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Adam Ibilger

SPECTROGRAPHIC OUTFITS

for

Metallurgical and General Chemical Analyses

NINTH EDITION

DAM HILGER LTD
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Spectrographic Outfits
for
Metallurgical and General Chemical Analyses

A GUIDE TO THE CHOICE OF SUITABLE SPECTROGRAPHIC APPARATUS FOR A TECHNICAL LABORATORY

NINTH EDITION
COMPLETELY REVISED

April, 1938

ADAM HILGER, LTD.
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PART I

Spectrographic Outfits for Metallurgical and General Chemical Analysis

INTRODUCTION

The increasing number of commercial applications of spectrographic technique in recent years have led us to add to this publication a very brief description of the underlying principles upon which the technique is based.

A complete account, even a severely condensed one dealing solely with the approved methods in vogue, is too lengthy for inclusion here, and is available in the Publishers' book "The Practice of Spectrum Analysis" (6th edition second impression, 1935; illustrated, 70 pages, price 3s. 6d. net; 3s. 8d. post free).

AN ELEMENTARY ACCOUNT OF SPECTRUM ANALYSIS.

(*Analysis of substances by means of their emission spectra.*)

So many accounts have been given of the nature and production of the emission spectrum that there is no need to do more than summarise its principles here.

A metal, when it is vaporised and suitably excited in a flame, an arc or a high tension spark, can be made to give out light. The light from each element is characterised by being composed of certain radiations (identified by their wavelengths) different from those in the light from other substances. There may be very many or only a few such radiations present. This light is always definitely characteristic of the metal used, but except in certain simple cases the unaided eye cannot appreciate this; the spectroscope or the spectrograph are necessary adjuncts for accomplishing such discrimination.

The **spectrograph** sorts out the various radiations and ranges them as lines upon a photographic plate (see reproduction on page 47) strictly in order of their wavelength, so that a measurement of the position of a line upon the plate determines its wavelength and hence leads to the identification of the substance emitting it.

A **spectroscope** enables the eye to become the substitute for the photographic plate.

All the constituents of a substance will at the same time emit their characteristic radiations, with the result that the one photograph exhibits complete evidence of the presence or absence of every metallic element contained in the specimen under test.

Some elements emit a very large number of radiations so that their spectra (that is, the assemblage of lines upon the photograph) consist of hundreds or even thousands of lines, while others emit but few radiations giving rise to only a few lines. It will be seen from this, that some elements require the lines to be more widely separated for identification of those other elements which may be associated with them to be possible. This property of separating the lines is spoken of as the dispersion of the spectrograph and if certain metals, mineral ores and rare earths are concerned an instrument of very large dispersion is required (see also page 14).

ADAM HILGER, Ltd., 98 Kings Road, Camden Road, London, N.W. 1

Only a small proportion of the radiations from a substance are visible ; the majority can only be recorded on a photographic plate. The notion of wavelength is familiar to most users of radio, so it may be stated at once that the waves of radiations of light are so small that they have to be measured in terms of the Angstrom (10^{-10} metres). Visible light has wavelengths between 3800 A and 8000 A approximately ; the invisible light used in spectrum analysis has wavelengths between 1850 A and 3800 A. Glass will not allow wavelengths below about 3500 A to pass through it so that the spectrograph should have its optical system (prism and lenses) made of a substance transmitting the ultra-violet, such as quartz.

With the actual construction of the spectrograph we are not here concerned. Any of the apparatus listed in this booklet can be efficiently used without such information. Externally it is a casing provided with a narrow variable slit and a photographic plate holder. Its actual shape may vary but these elements are common to all spectrographs. The light from the source enters the slit and its spectrum is formed on the photographic plate.

The specimen is usually caused to emit light by one or other of the following means. It may be introduced into (*a*) an electric arc, either by making pieces of material to be tested serve as electrodes or by placing a little of the material upon other electrodes, such as pure carbon or pure copper, or (*b*) a high tension spark may be passed between two specimens. In a limited number of cases the ordinary Meker flame may be used to excite the spectrum of the material. For special purposes there are other means of exciting the spectrum ; these will be found described more fully in various other books, such as those listed on pages 46-49. The light thus produced passes through the slit of the spectrograph, and its spectrum is recorded on the photographic plate, which is afterwards developed and fixed.

It is seen, then, that the actual taking of a spectrogram is not a difficult or complex process, especially with the modern apparatus originated by Adam Hilger, Ltd. When the instruments listed herein possess any adjustments at all they are few and simple. A spectrograph or spectroscope is far simpler to use than is the average metallurgical microscope.

The interpretation of the spectrograms when they have been taken is the only part of the process of spectrum analysis that requires skill and experience. It consists essentially in deciding upon the origin of the spectrum lines from a knowledge of their wavelengths. Even this is a much less formidable task with experience than it would at first appear. The user of these methods gradually gains such knowledge of spectra that he can identify many lines and groups of lines by simple inspection of the photographic plate. The task is further simplified by taking comparison spectra in which the spectrum of the unknown is placed in juxtaposition with that of a known substance whose presence or absence is deduced from the coincidence of its lines with lines in the spectrum of the unknown. This process is simplified further if use is made of such specially prepared products as the R.U. Powder (see pages 38-39) which provides comparison lines for about fifty elements at one exposure, or the Specpure Ratio Powders (see page 55).

To sum up. The advantages of spectrum analysis with apparatus of the Hilger type are (*a*) the simple, straightforward manipulation of Hilger Spectrographs; (*b*) the high degree of definition which permits ready discrimination between the lines even in complex spectra ; (*c*) the freedom from complex or difficult technique ; (*d*) the fact that a single exposure serves to reveal and record all the metallic contents of the specimen ; (*e*) the simplicity and robustness of their construction, which make the Hilger spectrographs capable of withstanding hard usage for many years without deterioration or loss of accuracy.

The user of Hilger spectrographic equipment is not faced with the necessity of investigating the construction of his spectrograph or learning how to perform more or less elaborate adjustments or replacements of optical or mechanical parts for varying purposes. Moreover, the carefully compiled handbook of instruction issued with each instrument provides all the information he requires for the employment of the many special methods which have been worked out of recent years for chemical analysis by emission spectra.

It is interesting to note that although Spectrum Analysis was discovered in 1861 it only began to be used in industry on the introduction about 1911 of the Hilger quartz spectrographs then known as A, C, and D, prototypes of the modern E 484, E 498 and E 492.

THE PRESENT-DAY POSITION OF SPECTROGRAPHIC ANALYSIS OF METALS.

It is a simple, certain and speedy matter, with such modern equipment as will be described, to detect the whole of the metallic constituents of any metals or alloys, as well as those of mineralogical preparations. New accessories are frequently being added, but all of them require similar basic apparatus ; *i.e.* a good spectrograph with such accessories as are included in the outfits on pages 17 to 24.

A most important feature of Spectrographic Analysis is that one photograph usually suffices for the detection and permanent record of all the metallic contents of a sample, even if the quantity is very small.

In the last few years much has been done to extend quantitative spectrum analysis as distinct from qualitative analysis. As a result of the work done in many laboratories, including our own, it appears that one can always determine with certainty the amounts of the minor metallic contents of a sample without recourse to the employment of special apparatus or accessories, although with varying accuracy. Even in *unfavourable* instances one can distinguish between 0·001, 0·01, 0·1 and 1·0 per cent. of any metallic impurity by simple visual comparisons of the intensities of the lines. In favourable instances, and with the same simple means most observers obtain an accuracy of about 10% of the substance sought. The estimation is, of course, very rapid—one half hour will suffice for the whole procedure of photography, developing, and estimation ; and the plate forms a permanent record of the whole metallic contents of the sample. Further, with the aid of a non-recording microphotometer the blackening of a spectrum line may be directly measured thus eliminating errors of judgment such as were formerly common (see page 25). A high accuracy is also attainable with certainty if various accessories and methods introduced during the past five years or so are used ; a variation of 5% in the amount of either a minor or major constituent can generally be distinguished. These accessories and methods are described in Parts II and IV.

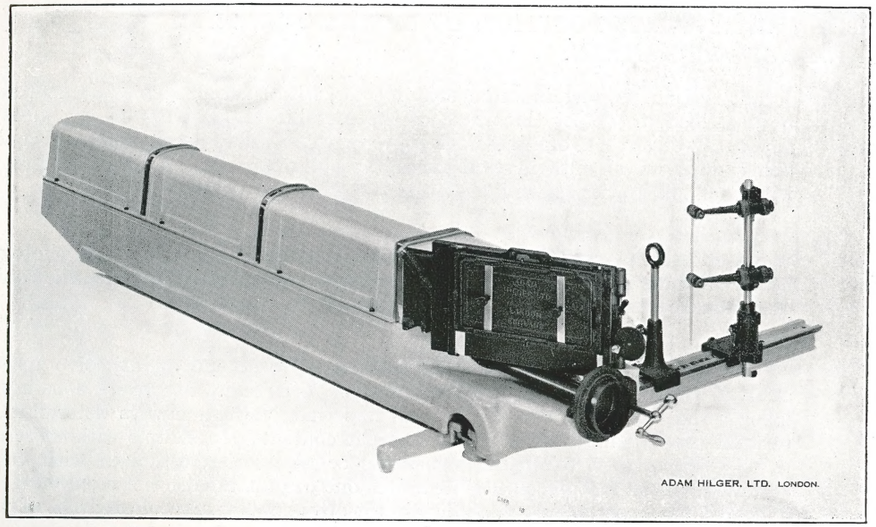
Using a microphotometer (see page 25) an accuracy of 2% has been attained in some laboratories in favourable cases (Lundegårdh, Duffendack) using solutions.

SPEEDING-UP SPECTROGRAPHY.

The rapidly widening use of the spectrograph in industry has brought an increased appreciation of the value of devices for hastening the work.

The latest Hilger Quartz Spectrographs with the bar for mounting the accessories (described on pages 7 to 13) leave nothing to be desired as far as the alignment of apparatus and actual photography are concerned, while the usual methods for hastening development, fixing, washing and drying of the plate are well known.

The subsequent processes of identifying the lines and measuring wavelengths have therefore recently been engaging the attention of the Hilger Laboratories, with the result that we can now offer an extremely rapid spectrum comparator (see page 42) whereby lines can be identified, and wavelengths estimated, quickly and comfortably.



E 492.—BARFIT FULLY AUTOMATIC LARGE QUARTZ SPECTROGRAPH with Standard Hilger Accessory Bar, Condensing Lens and Gramont Arc and Spark Stand

THE PRINCIPAL HILGER SPECTROGRAPHS FOR SPECTROGRAPHIC ANALYSIS

THE AUTOMATIC LARGE QUARTZ SPECTROGRAPH (F_D 170 cm.).

For comparatively complex spectra, such as are given by alloy steels, minerals, ores, etc., it is necessary to use an instrument of great dispersion. The large quartz spectrograph fulfils the requirements. It is available in three forms, of which the one specially recommended for analytical work is the Fully Automatic Large Quartz Spectrograph. Such large dispersion instruments take the total length of spectrum in three or more ranges ; the distinguishing feature of the Fully Automatic Spectrograph is that the three adjustments usually necessary for each such range are made simultaneously by one control. A brief specification follows (for illustration see page 6).

In permanent adjustment.

Construction. All Metal.

Prism. Quartz 30° prism with refracting face 93 mm. long × 56 mm. high. The light is reflected from the back face.

Lens. Quartz, focal length for D.170 cm., diameter 75 mm.

Slit. Hilger F 31, with stainless steel jaws, wedge diaphragm and three aperture diaphragm, shutter behind jaws.

Plateholder. One plateholder is supplied taking 10 × 4 in. plates. If desired plateholders for 10 × 2 in., or 9 × 24 cm. plates can be supplied.

All the plateholders are accurately interchangeable and extra plateholders of any of the sizes can be supplied at any time.

Range of Spectrum. 1910 A to 8000 A.

Length of Spectrum. Between 2000 A and 8000 A, 67 cm. approximately.

Scale. A millimetre scale similarly mounted to the wavelength scale of E 498 is provided (see page 10).

The Base of the spectrograph is constructed to take the Standard Hilger Accessory Bar, or one 72 ins. in length, on which a number of accessories can be mounted. The length of the bar available for accessories is about 85 or 160 cms. The bar (actually it is an accurate optical bench) is of a special form which presents advantages, both of rigidity and accuracy of location of the accessories, over the triangular bar frequently employed. It is so mounted on the spectrograph that it is automatically held rigidly in alignment with the optical axis while its design and the arrangement of the riders used with it maintains the line of centres correct even when the riders are reversed. The bar has been aged by heat treatment. A second, shorter bar, suitable for storing accessories not in use, can be supplied.

E 492.—Hilger Automatic Large Quartz Spectrograph with internal mm. scale	£425 0 0
E 481.—Bar for Accessories	7 15 0
E 482.—Short Bar 21 in. long for carrying accessories not in use	6 15 0

OTHER MODELS OF THE LARGE QUARTZ SPECTROGRAPH.

Simpler, less expensive models of the Large Quartz Spectrograph are also available. Except that the adjustments are not automatic, and the bases are not adaptable to the accessory bar their optical specification is similar to that of E 492.

E 383.—Large All-Metal Quartz Spectrograph without mm. scale £327 0 0

E 384.—Large, All-Metal, Quartz Spectrograph, as E 383, above, but fitted with internal millimetre scale which can be printed on the plate in juxtaposition to the spectrum, together with calibration curves 347 0 0

When using these instruments it is necessary to set three separate adjustments for any region of the spectrum. Four such sets of adjustments are specified in the instructions for use of the spectrograph, so chosen as to cover the whole spectral range of the instrument in four approximately equal, slightly overlapping sections.

THE MEDIUM QUARTZ SPECTROGRAPH (F_D 60 cm.).

As the result of new computations of the optical system we now offer a medium quartz spectrograph in which the image field is quite flat and which gives very fine definition over the whole spectrum range without readjustment.

Fine definition of uniform quality over the whole photographic plate is even more important than formerly now that the use of the microphotometer is increasing.

An incidental advantage is the absence of trouble from plate breakage whatever thickness of plate is used.

This is the most frequently used size of Hilger Spectrograph. It has recently been completely redesigned and in its latest form (E 498) it is exceedingly useful and convenient. A brief specification is given below, further particulars are to be found in Hilger Publication No. 264, free on application.

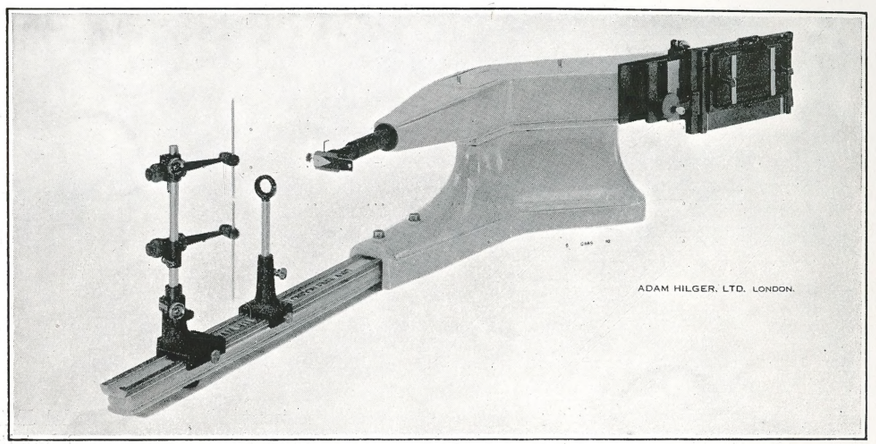


Fig. E 498

In permanent adjustment ; always ready for use.

Construction. All Metal.

Flat Field. No curvature in the plateholder.

Prism. Quartz Cornu Prism, 65 mm., length of face, 41 mm. high.

Lenses. Crystalline Quartz, 24 in. (610 mm.) focus for D. Aperture 2 in. (51 mm.). Figured by means of Hilger interferometers and computed to give a flat field.

Slit. Hilger F 31, with stainless steel jaws, shutter for exposure, wedge and three-aperture diaphragms.

Spectrum from 2000 A to 10,000 A, 230 mm. long approximately.

Plateholder. One plateholder is supplied taking 10 × 4 in. plates. If desired plateholders for 10 × 2 in. or 9 × 24 cm. plates can be supplied. The chassis which carries the plateholder, and from which the latter is very easily removed for loading,

is raised and lowered by a worm operated rack and pinion gear with a spring detent which arrests the movement of the plateholder at one mm. intervals. This simple device greatly increases the speed of operation where numbers of spectra must be taken on the one plate.

All the plateholders are accurately interchangeable and extra plateholders of any of the sizes can be supplied at any time.

Wavelength Scale. The E 498 spectrographs are fitted with an accurate scale of wavelengths mounted internally in such a manner as to be brought at will in contact with the photographic plate. A lens system is so fitted that any light source placed close to the instrument illuminates the scale, and a contact print of the wavelength scale can thus be obtained on the same plate as, and in juxtaposition to, the photograph of the spectrum.

Bar for Accessories. The base of this spectrograph is made to fit the Standard Hilger Accessory Bar exactly similar to that used with E 492 (page 7).

E 498.—Barfit Medium Quartz Spectrograph, F_D 60 cms. with base to fit Standard Hilger Accessory Bar, internal wavelength scale and one plateholder for 10 × 4 in. plates	£251 0 0
E 501.—Extra plateholder taking plates 10 × 4 in.	12 10 0
E 502.— ,, ,, ,, ,, 10 × 2 in.	12 10 0
E 481.—Bar for Accessories	7 15 0
E 482.—Short Bar—21 in. long for carrying accessories not in use	6 15 0

For those requiring a less expensive instrument, the earlier model E 488 is still available. In general appearance it is closely similar to the E 498 but it uses a curved plate. It gives excellent definition but the curvature renders it less suitable for use with the microphotometer.

E 488.—Barfit Medium Quartz Spectrograph with internal wavelength scale and base to fit Standard Hilger Accessory Bar	£224 0 0

INTERMEDIATE QUARTZ SPECTROGRAPH (F_D 38 cm.).

An addition to the Hilger range of spectrographs, intermediate in dispersion and price between E 484 and E 498. The following is a brief specification of the instrument.

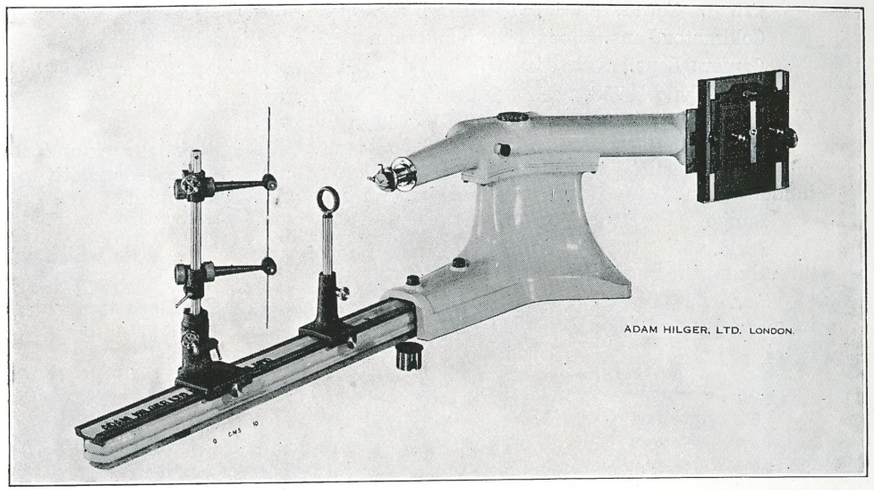


Fig. E 486

In permanent adjustment ; always ready for use.

Construction. All Metal.

Prism. Quartz, Cornu, 60° angle, 30 × 39 mm. face.

Lenses. Crystalline quartz, { Collimator, diam. 33 mm., focal length 395 mm. / Camera, diameter 54 mm., focal length 374 mm.

Slit. Hilger type F 758, with stainless steel jaws, three aperture and wedge diaphragm, shutter behind jaws.

Size of Plate. 7 ins. × 5 ins. Plate holder has rack-and-pinion movement.

The field of this instrument, and hence the plate, is flat.

Range of Spectrum. 2000 A to 10,000 A.

Scale. A scale of wavelengths is fitted internally.

Bar. The standard bar for accessories can be fitted to this instrument (see description of E 492, page 7).

E 486.—Intermediate Quartz Spectrograph F_D 38 cms. with internal wavelength scale	£150 0 0
E 481.—Standard Hilger Bar for Accessories	7 15 0
E 482.—Short Bar—21 inches long, for Accessories not in use. ...	6 15 0

SMALL QUARTZ SPECTROGRAPH, E 484 (F_D 20 cms.).

SPECIFICATION.

In permanent adjustment ; always ready for use.

Construction. All Metal.

Prism. Cornu, quartz, 60° angle, 17 × 22 mm. face.

Collimator Lens. Focal length 208 mm. (8·2 ins.), diameter 19 mm. (0·75 ins.).

Camera Lens. Focal length 197 mm. (7·7 ins.), diameter 26 mm. (1·10 ins.).

Slit. Type F 758, with stainless steel jaws, screw adjustment, three aperture diaphragm and wedge diaphragm, shutter behind jaws.

Size of Plate. $4\frac{1}{4}$ ins. × $3\frac{1}{4}$ ins. (10·8 × 8·2 cm.). Plate holder has rack-and-pinion movement. Thirty or more spectra can be taken on one plate. Alternative plate holders for plates 9 × 12 cm. or 5 × 4 ins. can be supplied on request.

Range of Spectrum. 1850 A to beyond 8000 A.

Scale. Model E 484 is fitted with an internal wavelength scale which prints directly on the negative.

Bar. The accessory bar ensures accurate alignment of the spectrograph with its accessories and holds them rigidly.

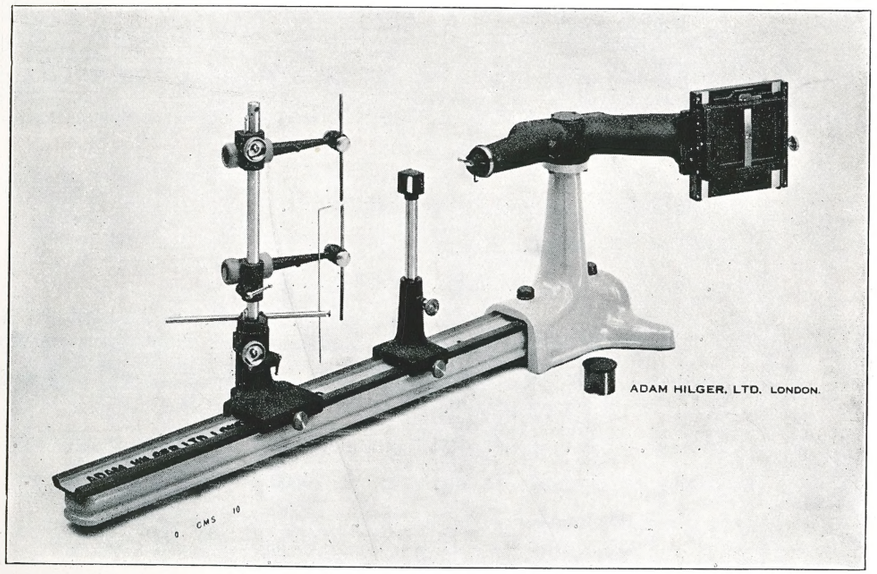
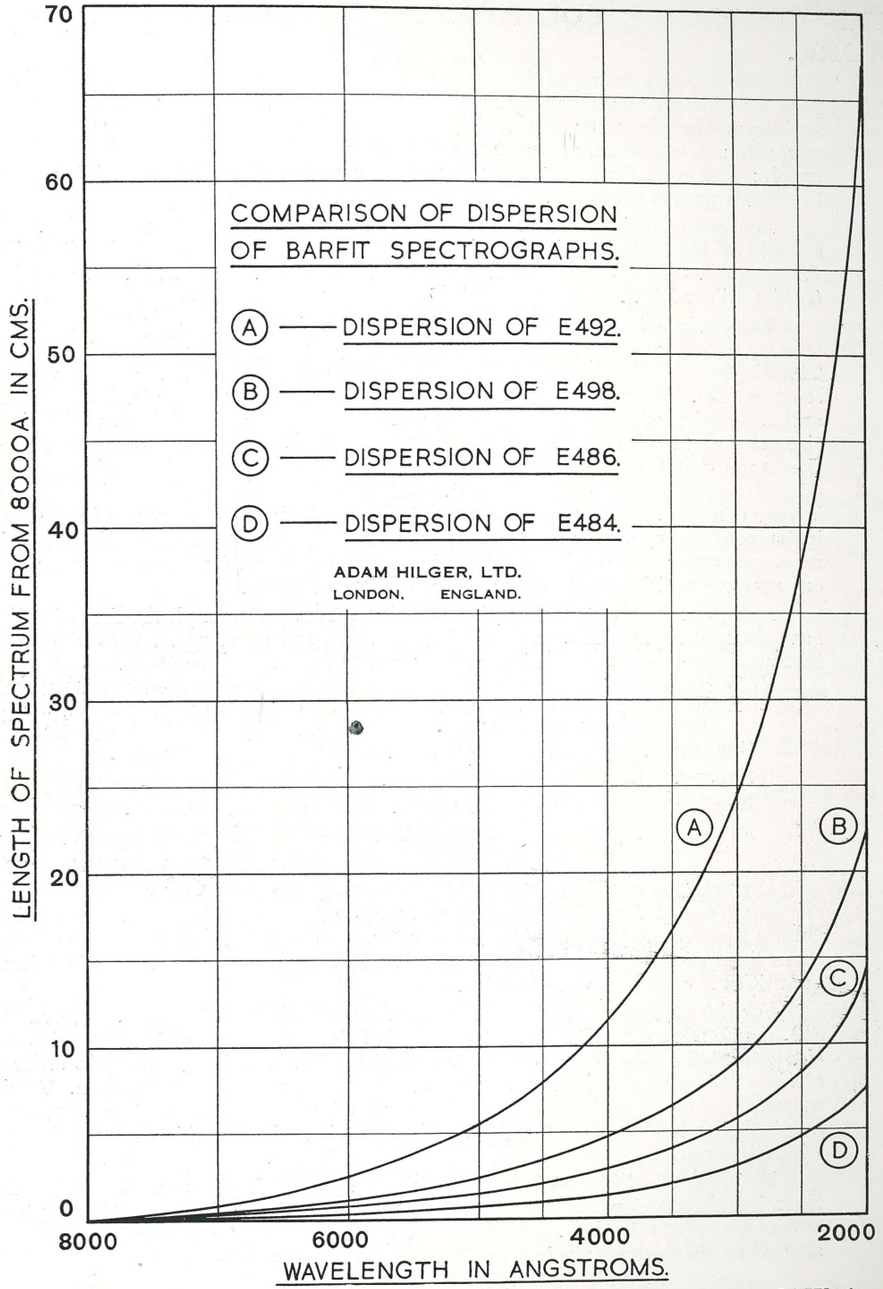


Fig. E 484—F 946—F 956—E 481
Quartz Spectrograph A with Accessory Bar, Gramont Arc and Spark Stand, and Condenser.

E 484.—Quartz Spectrograph F 20 cm. fitted with internal wavelength scale on stand to fit accessory bar	£85	0	0
E 481.—Standard Hilger Bar for Accessories	7	15	0
E 482.—Short Bar—21 in. long for carrying accessories not in use	6	15	0



THE CHOICE OF EQUIPMENT FOR METALLURGICAL WORK.

A complete spectrographic outfit consists of a spectrograph with a supply of photographic plates ; means of producing radiation from the substance under test, such as an electric arc or spark, with electrodes of a few pure metals for comparison purposes ; a condensing lens for concentrating the light on the slit of the spectrograph ; and some form of comparator or other means of examining and interpreting the spectrograms produced.

For metallurgical analysis the quartz spectrograph is recommended. An account of the technique is given in *The Practice of Spectrum Analysis with Hilger Instruments*. 6th edition second impression. Price 3s. 6d. nett, 3s. 9d. post free. (Adam Hilger Ltd.).

The choice of spectrographs lies between four sizes, the Large (E 492), Medium (E 498), Intermediate (E 486) and Small (E 484) quartz spectrographs of our range. The dispersions of these instruments are in the proportions 9, 3, 1·9, 1 (for details see page 13). For most work with non-ferrous metals (for example, the detection and estimation of impurities in brass, zinc, lead, copper, aluminium, magnesium, tin, gold, etc.), the Medium size has ample dispersion, and has the advantage over the Large that the whole spectrum is obtained on a single plate on which a scale of wavelengths can be photographed. Where the spectrum of the main substance is very complex, the large spectrograph is required. The full spectrum in the large instrument extends over four plates, but a sufficient range of distinctive lines for most purposes can often be photographed on one plate, while the change over from one spectral position to the other is very easily performed.

As a guide to the selection of a suitable quartz spectrograph the following lists have been compiled of elements whose spectra are so complex that the Large instrument is necessary when impurities are to be detected in them.

Metals for which the Large E 492 Spectrograph is necessary.		Metals for which the Large E 492 Spectrograph is desirable, but not essential.
Chromium.	Titanium.	Manganese.
Cobalt.	Tungsten.	Thorium.
Iron.	Uranium.	Vanadium.
Molybdenum.	Zirconium.	Platinum Group.
		Nickel Alloys.

It should be observed that in most cases where metals other than the above are being tested for the presence or absence of the above metals, the Medium Quartz Spectrograph has sufficient dispersion for the work, as the number of spectrum lines corresponding to these metals when they are only present in minute quantities is generally not excessive.

For the routine examination of some elements in steel alloys (*e.g.* Ni., Cr., and Si.), it has been found that the dispersion of the medium size instrument is sufficient. But for other elements the larger dispersion is to be preferred in order to obviate the risk of lines of such elements being obscured by those of iron. Again, unsuspected elements (which may be a source of trouble in an alloy) are sometimes overlooked when the medium instrument is used, whereas this does not happen with the large one.

The larger instrument has a further advantage ; for quantitative work using the microphotometer it is always advisable to work with as wide a spectrograph slit as possible (even 0·1 mm. is not too large) and this is impossible with a complex steel alloy on the medium instrument since the lines would overlap.

The reason for the use of a wide slit is to overcome errors due to grain of the plate and this is important in the use of the microphotometer.

The ease with which lines can be detected (without high magnification of the plate) and the need at times for a complete analysis of a material lead us definitely to recommend the use of the larger instrument for steels and the other metals referred to in columns 1 and 2. Its value has already been definitely proved in a number of commercial laboratories.

The Intermediate (E 486) and Small (E 484) spectrographs are both capable of useful work within the scope of their dispersions. The small size was used by Brownsdon and van Someren * in the routine works analysis of brass for the determination of lead, tin, iron, nickel, aluminium and manganese, and for similar analyses of lead and lead alloys for tin, antimony, cadmium, arsenic, bismuth, copper, zinc and silver ; the intermediate size is suitable for soil analysis by the flame method of Lundegårdh.

Smith † has also used a small spectrograph (see Outfit III), with a wavelength scale and, on occasion, a logarithmic sector, for the assaying of ternary lead alloys, such as are used for cable-sheathing, etc., whilst an article on "Rapid Quantitative Analysis of Magnesium and Magnesium Basis Alloys by means of the Spectrograph" was based largely on investigations with such an outfit. Smith‡ has also used the outfit for the determination of cadmium, lead and iron in zinc to conform to the limit of the British Standards Institute specifications.

A difference in technique exists between the method of Brownsdon and van Someren and that of Smith in that the latter employs a condensing lens whilst the former workers dispense with this. The sphero-cylindrical condenser F 956 should therefore be included in the outfit when Smith's technique is to be adopted.

This small outfit has also been employed for the determination of the purity of galvanised coatings and it may be said that, in general, for the non-ferrous metals and alloys which give simple spectra the small spectrograph is capable of giving highly satisfactory results both for qualitative work and for quantitative work where the percentages of the alloying constituents are small.

Finally, it is of interest to note that the British Post Office Engineering Department have investigated the logarithmic sector method having regard to its suitability for testing cable-sheathing for conformity with their specifications. It was found that the method was eminently suitable and the Department accordingly recommended its adoption by cable makers. The results of the investigation are contained in the Department's Research Report No. 5651. It should be noted that for this research the only instrument available in the Department's laboratories was of the early large E 1 type (F_D 170 cms.), but the results and conclusions arrived at are equally applicable to the small outfit No. III.

* "Application of the Spectrograph to the Analysis of Non-Ferrous Metals and Alloys", Brownsdon and van Someren, *J. Inst. Metals*, xlvi. 97 (1931).

† "The Spectrographic Assay of Some Alloys of Lead," Smith, *Trans. Faraday Soc.*, **26**, 101 (1930).

‡ "The Spectrographic Determination of Cadmium, Lead and Iron in Zinc," Smith, *Trans. Faraday Soc.*, **26**, 101 (1930).

Use of Microphotometer.

Recent work has shown that for routine quantitative analyses the speediest and most accurate results are obtained by means of the microphotometer.* The latest model of our Non-Recording Microphotometer embodies features which assist materially in increasing the speed and certainty with which analyses may be performed.

Advice on Choice of Apparatus.

We have built up a very comprehensive collection of information on applied spectrum analysis, partly by the study of published information, partly by the courtesy of those who have given us advanced information of their work or of unpublished applications. We are constantly adding to such information and are, consequently, in an unique position to assist and advise clients as to the apparatus or methods best suited to their special problems. Such information is given freely on receipt of particulars of the work to be undertaken.

In the following lists the three main outfits include *everything necessary* for the application of spectrum analysis to metallurgy. Other outfits for special purposes are indicated. Where the work is limited to a particular set of tests some of the accessories can be omitted, while for some work additional accessories selected from those in Sections III and IV are useful.

The considerations governing the choice of the type of light-source to be employed are discussed in the book "The Practice of Spectrum Analysis" already mentioned.

For economy in (*a*) time, (*b*) photographic plates, for convenience and avoidance of fatigue, for precision and general efficiency it is desirable to include in the equipment a Spectrum Comparator or projector (see pp. 41-43). It increases refinement for those with experience and is extremely useful for the comparison of complex spectra.

For Mineralogical Work almost exactly similar outfits are required. A complete equipment is listed on pages 19 and 20.

For Absorption Spectrophotometry additional accessories are required. See Hilger Publication No. 156.

* See Twyman, Lothian and Dreblow, *J.S.C.I. 57*, 75-79. (March 1938).

RECOMMENDED OUTFITS FOR SPECTROGRAPHIC ANALYSES

The following are our carefully considered recommendations for Outfits for Spectrochemical Analysis.

The accessories selected are in each case the most suitable that are at present available for the particular types of work in question.

Each outfit is designed to include every essential item for the particular use it is intended to fulfil.

The accuracy obtainable with the recommended equipment will suffice for most problems which only require a semi-quantitative solution. For accurate quantitative work in routine analysis a microphotometer is desirable. For non-routine determinations one of the quantitative methods referred to on pages 50-56 can be employed.

For the guidance of those who have acquainted themselves with the recent, plentiful contributions to the technique of spectrum analysis, it should be pointed out that in this book will be found all the accessories necessary for carrying out any of the methods described.

I.—OUTFIT (WITH MEDIUM SPECTROGRAPH) FOR METALLURGY and suitable for any materials except those with very complex spectra (see page 14).

	For Details see Pages	
Spectrograph and Condenser.		
E 498.—Barfit Medium Quartz Spectrograph with wave-length scale	9-10	£251 0 0
E 481.—Bar for Accessories	10	7 15 0
F 958.—Quartz spherical Condenser, on raising and lowering stand to fit bar...	30	4 15 0
Arc Outfit.		
F 946.—Gramont Arc and Spark Stand to fit bar ...	32	16 5 0
F 947.—Metal Resistance Box, for currents up to 8 amps, complete with ammeter ...	34	5 5 0
Spark Outfit ; add the following items.		
F 282.—$\frac{1}{4}$ K.W. Transformer and Auto-transformer	35-6	20 0 0
F 283.—$\frac{1}{4}$ K.W. Condenser	35-6	11 5 0
F 285.—Hemsalech Self-induction Coil	36	5 0 0
High Purity Electrodes.		
F 948.—H.S. Brand Copper, 6 pairs	37	1 10 0
F 693.—H.S. Brand Electrolytic Iron, 6 pairs ...	37	2 5 0
F 623.—H.S. Brand Graphite, 6 pairs	37	1 10 0
Spectrum Maps (photographic).		
F 304.—Maps of the copper arc spectrum	46	1 5 0
Photographic Plates.*		
F 1118.—6 doz. Ilford Ordinary Plates, 10 in. × 4 in....	45	3 7 6
F 644.—Negative Viewing Stand	40	1 18 6
		£333 1 0

* See also page 45 for suitable alternatives.

Literature.

	For Details see Pages	
F 146.—*Wavelength Tables for Spectrum Analysis*, by F. Twyman and D. M. Smith ...	46	£0 14 6
***F1064.**—*Die Chemische Emissionsspektralanalyse*, Part 3 (Gerlach and Riedl)	49	0 10 6
F 867.—*Metallurgical Analysis by the Spectrograph*, by D. M. Smith	49	0 10 6
Total necessary outfit		£334 16 6

Each Spectrograph is accompanied by a copy of—

F 305.—*The Practice of Spectrum Analysis with Hilger Instruments*, 6th edition (which gives a description of the technique). *Extra copies can be obtained* 46 £0 3 6

ELECTRIC SUPPLY.

ARC.

An arc between metal or graphite rods requires Direct Current. If the mains supply is Alternating a convertor or motor-generator set must be used. A suitable machine is the following :

F 732.—Motor Generator Set AC-DC £30 0 0

The Set consists of : Induction motor wound for operation on A.C. supply (*state voltage, phase and periodicity of mains when ordering*) direct coupled by flexible coupling, on combined bed plate, with Open Protected shunt-wound Generator having a *continuous* D.C. output of 5 amps. at 200 volts, or for short intermittent periods up to 8 amps., complete with starter and shunt field regulator.

SPARK.

The transformer for Spark work requires Alternating Current. If the mains supply is Direct a motor alternator must be used.

F 281.—¼ K.W. Motor Alternator D.C.-A.C. £20 0 0

110 volts D.C. to 75 volts 60 cycles A.C. or 220 volts D.C. to 150 volts 60 cycles A.C.

(*State D.C. mains voltage when ordering.*)

SPECIAL NOTE.

Recently there have been introduced elaborate and necessarily costly spark generators for which special claims have been made. We have, however, made careful investigation of the degree of inaccuracy that is likely to be occasioned by the use of our own simple transformer, condenser and inductance set and find that, while fluctuations do occur, the ratio of intensity of two spectrum lines does not depart from constancy by more than 4%.

Work recently performed in our laboratories on the quantitative spectrographic analysis of aluminium alloys has proved that using the standard Hilger ¼ k.w. spark equipment an accuracy of ±5% of the concentration is consistently attainable.

No data have been published to show that the constancy attained by the more complex apparatus is any greater.

Thus, as a consequence of our investigations, we recommend the use of our simple and inexpensive sparking equipment.

For additional apparatus necessary for Quantitative Spectrum Analysis see pages 25-29 *and* 50-56.

* Published abroad, price subject to fluctuation.

Ia.—OUTFIT (WITH MEDIUM SPECTROGRAPH) FOR MINERALOGY.

This outfit is as specified above (Outfit I) except for the addition of such accessories as are necessary for carrying out investigations by the Carbon Arc Cathode Layer (Glimmschicht) Method described by L. W. Strock, and used by Prof. V. M. Goldschmidt W. R. Mannkopf and their co-workers at Göttingen.

This is a suitable outfit for many substances whose spectra are not too complex but we recommend for general use Outfit No. 2 A overleaf.

	For Details see Pages	
Outfit No. I complete as specified	17-18	£334 16 6
F 1083.—Mirror, Lens and Diaphragm condensing system	30-32	19 15 0
F 1067.—1 doz. Carbon Electrodes with hole, 1 mm. diam., 2 mm. deep	37	1 1 0
F 1068.—1 doz. Carbon Electrodes with hole, 0·8 mm. diam., 6 mm. deep	37	1 1 0
F 890.—1 doz. H.S. Carbon Rods		3 5 0
F 1069.—1 Copy "Spectrum Analysis with the Carbon Arc Cathode Layer" by Lester W. Strock	49	0 5 6
Total Outfit No. Ia		£360 4 0

Ib.—OUTFIT (WITH MEDIUM SPECTROGRAPH) FOR GENERAL CHEMICAL ANALYSIS.

This outfit is as specified above (Outfit No. I) except for the following additional items and a small supply of "Specpure" Ratio Powders selected from those listed in Hilger Publication No. 168 as appropriate to the problems anticipated.

Outfit No. I complete as specified but without condensing lens F 958		£330 1 6
F 1026.—Quartz Condensing Lens (see page 32)		4 15 0
F 713.—Pellet making Block	(*See Specpure Booklet*)	1 5 0
F 890.—H.S. Highly Purified Carbons, one pair ...		0 15 0
F 711.—"Specpure" Ammonium Sulphate, 50 gms.		0 8 6
L 46.—Judd Lewis Spectrum Comparator (see page 42)		43 0 0
L 49.—Scale for L 46		4 10 0
Total Outfit No. Ib		£384 15 0

Ic.—OUTFIT (WITH MEDIUM SPECTROGRAPH) FOR SOIL ANALYSIS (see also Outfit IV.).

This outfit is identical with Outfit No. I (above) except for the omission of the spark set (F 282, F 283, F 285 and F 281) and the addition of the following :

It is suitable for Soil Analysis by the Arc Method used by H. Milbourne (*J. Soc. Chem. Ind.* 56, 205T-209T, 1937).

Another outfit for Soil Analysis by Prof. H. Lundegårdh's Flame Method will be found on pages 22-23.

	For Details see Pages	
Outfit No. I without spark outfit	17-18	£298 11 6
F 713.—Pellet making Block...	55-56	1 5 0
F 890.—Highly Purified Carbons, one pair	37	0 15 0
F 711.—" Specpure " Ammonium Sulphate, 50 gms.	55-56	0 8 6
L 46.—Judd Lewis Spectrum Comparator	42	43 0 0
Total Outfit No. Ic		£344 0 0

To this must be added a supply of suitable **" Specpure " Ratio Quantitative Powders** selected from Hilger Publication No. 168.

II.—OUTFIT (WITH LARGE SPECTROGRAPH) FOR ANY PROBLEM.

Spectrograph and Condenser.	For Details see Pages	
***E 492.—Fully Automatic Large Quartz Spectrograph**	7	£425 0 0
E 481.—Bar for accessories	7	7 15 0
F 958.—Quartz Spherical Condenser on mount to fit bar	30	4 15 0
Arc Outfit, **Spark Outfit**, **High Purity Electrodes**, **Photographic Plates**, **Literature** } As specified for Outfit I	30-49	71 6 6
F 532.—Enlargements of the iron arc spectrum ...	46	2 5 0
Total necessary outfit		£511 1 6

(*For additional apparatus necessary for Quantitative Spectrography see* II. *pages* 25-29 *and* V. *pages* 50-56.)

IIa.—OUTFIT (WITH LARGE SPECTROGRAPH) FOR APPLICATION TO MINERALOGY.

This outfit is recommended by us for spectrographic investigation of all minerals.

	For Details see Pages	
E 492.—Large Fully Automatic Quartz Spectrograph	7	£425 0 0
E 481.—Bar for Accessories	7	7 15 0
F 997.—Quartz Sphero-cylindrical Condenser ...	30	7 5 0
F 946.—Gramont Arc and Spark Stand	32	16 5 0
F 947.—Metal Resistance Box	34	5 5 0
F 693.—1 doz. pairs H.S. Electrolytic Iron Rods ...	37	4 0 0
F 623.—1 doz. pairs H.S. Graphite Rods	37	2 10 0
		£468 0 0

* Particulars and prices of other instruments which give the same length of spectrum as E492 will be found on page 8.

	For Details see Pages	*Bro't Forw'd*	
		£468	0 0
F 532—Set of Enlarged Photographs of Iron Arc Spectrum	46	2	5 0
F 1016.—6 doz. Ilford Zenith Plates, 10 in. × 4 in....	45	3	7 6
F 142.—6 doz. Ilford Rapid Process Panchromatic Plates, 10 in. × 4 in.	45	3	13 6
F 146.—" Wavelength Tables for Spectrum Analysis "	46	0	14 6
F 558.—Tube R.U. Powder, containing 2 grams ...	39	2	10 0
F 559.—Enlargement of Spectrum of R.U. Powder	39	3	15 0
F 1067.—1 doz. Carbon Rods with hole 1 mm. diameter, 2 mm. deep	37	1	1 0
F 890.—1 doz. H.S. Carbon Rods	37	3	5 0
F 1068.—1 doz. Carbon Rods with hole 0·8 mm. diameter, 6 mm. deep	37	1	1 0
F 1083.—Mirror, Lens and Diaphragm	30-32	19	15 0
L 46.—Judd Lewis Comparator	42-43	43	0 0
L 49.—Scale for Judd Lewis Comparator	43	4	10 0
H 451.—Non-recording Microphotometer, with fine slow motion	25-27	110	0 0
H 405.—Photocell Unit	27	12	0 0
F 878.—Cambridge d'Arsonval Galvanometer ...	27	4	15 0
F 93.—Lamp and Scale	27	4	0 0
F 1045.—Variable Shunt	27	4	15 0
		£692	7 6

III.—OUTFIT (WITH SMALL QUARTZ SPECTROGRAPH) FOR ANALYSES OF SIMPLE SPECTRA, AS FOR LEAD, LEAD ALLOYS AND BRASS. Suitable where D.C. electric supply of from 150 to 250 volts is available.

	For Details see Pages	
E 484.—Small (F_D 20 cms.) Quartz Spectrograph, with Wavelength scale	12	£85 0 0
E 481.—Bar for Accessories	12	7 15 0
F 946.—Gramont Arc and Spark Stand	32	16 5 0
F 947.—Metal Resistance Box	34	5 5 0
F 1017.—6 dozen Ilford Zenith Plates, $4\frac{1}{4}$ in. × $3\frac{1}{4}$ in.	45	0 15 0
F 875.—Negative Viewing Stand, $4\frac{1}{4}$ in. × $3\frac{1}{4}$ in. ...	40	0 7 0
F 948.—H.S. Brand Copper Rods, 3 pairs	37	0 15 0
F 304.—Maps of the Copper Arc Spectrum	46	1 5 0
Complete Outfit No. III		£117 7 0

Optional.

F 956.—Spherocylindrical Quartz Condenser on raising and lowering stand to fit accessory bar E 481	30	£7 5 0

ADDITIONAL ACCESSORIES.

A. *For the use of Spark Spectra*
(Where A.C. * is available.)

F 282.—$\frac{1}{4}$ K.W. Transformer, with auto-transformer for all A.C. voltages from 75 to 220 ...	35-36	£20 0 0
F 283.—$\frac{1}{4}$ K.W. Condenser	36	11 5 0
F 285.—Hemsalech Self-Inductance Coil	36	5 0 0
		£36 5 0

* See page 18 " Electric Supply."

continued on next page

B. *For the use of the Logarithmic Wedge Sector.*
To the outfit above the following additions should be made.
For details see pages 52-54.

	For Details see Pages	
H 444.—Logarithmic Sector, for use with E 484 mounted to fit accessory bar	52-53	* £24 0 0
H 441.—Quartz Condensing Lens	52-53	4 15 0
H 217.—Eyepiece, with Internal Scale	54	3 10 0
		£32 5 0

IN ORDERING, PLEASE STATE VOLTAGE AND CHARACTERISTICS OF ELECTRIC SUPPLY.

IV.—OUTFIT WITH INTERMEDIATE QUARTZ SPECTROGRAPH FOR THE FLAME METHOD OF PROF. H. LUNDEGÅRDH. ESPECIALLY FOR SOIL ANALYSES.

The E 486 spectrograph included in this outfit is also suitable for the examination of simple arc and spark spectra.

Spectrograph.

	For Details see Pages	
E 486.—Intermediate Quartz Spectrograph (F_D 38 cms.) with internal wavelength scale ...	11	£150 0 0
E 481.—Bar for Accessories	11	7 15 0

Light Source.

The following accessories (F 998 to F 1002) are specially prepared for us under the personal direction of Prof. H. Lundegårdh of Uppsala. They are described on pages 28-29.

	Price† in Great Britain.	Price† Abroad (without duty).
F 998.—Complete Burner and Atomiser Assembly, including burner with platinum top, and stand fitting accessory bar E 481, platinum atomiser, one sprayer vessel, stands	£78 18 0	£53 8 0
F 999.—Two Manometers for acetylene and for air, the pair	11 7 0	7 15 0
F 1000.—Water Manometer for control of gas pressure, rubber tubes and brass cock for connecting the burner	6 15 6	4 10 0
F 1001.—Brass Cock and Rubber Tubes for connecting the atomiser, brass connections for tubes	4 15 0	3 0 0
F 1002.—Electrical Shutter for the spectrograph on stand to fit accessory bar E 481 with lamp resistance and switch	14 11 3	9 15 0

Photographic Plates.

	For Details see Pages	
F 1018.—6 dozen Ilford Zenith Plates, 7 in. × 5 in.	45	£1 13 0

Microphotometer.

H 451.—Hilger Non-recording Photoelectric Microphotometer, basic instrument fitted with fine-slow motion	25-27	110 0 0
H 458.—Ratchet Attachment for cross movement of plate	25-27	25 0 0
H 405.—Photo-cell Unit for emission spectra ...	25-27	12 0 0

* For A.C. If fitted with D.C. motor the price is decreased by 15s. 0d.
† Prices liable to fluctuate with rates of exchange.

Microphotometer—contd.

	For Details see Pages	
F 1045.—Variable Shunt for microphotometer ...	£27	£4 15 0
F 878.—Cambridge-d'Arsonval Galvanometer, 700 ohms resistance approx.; sensitivity at 2 metres, 1000 mm. per micro-amp. (made by the Cambridge Instrument Co., Ltd., London and Cambridge)	27	4 15 0
F 93.—Lamp and Scale for galvanometer (4 volt)	27	4 0 0

(Made by the Cambridge Instrument Co., Ltd., London and Cambridge.)

Literature.

F 996.—*Die Quantitative Spektralanalyse der Elemente* (Part II) H. Lundegårdh (cloth covered edition)	49	† 1 3 6
Total Price † Inland *		£437 8 3
Total Price † Abroad ex. our works		£399 9 6

Accessories and Spares.

It is recommended by Prof. Lundegårdh that the following accessories and spare parts should be added to the above outfit, which contains the bare necessities with the exception of gas and air supplies.

(*The items F* 1003 *to F* 1008 *are specially prepared for us under the personal supervision of Prof. H. Lundegårdh of Uppsala.*)

	Price† in Great Britain.	Price† Abroad (without duty).
F 1003.—Three Spare Sprayer Vessels	£8 0 0	£5 8 0
F 1004.—Wooden Stand for four sprayer vessels ...	2 5 0	1 10 0
F 1005.—Burner Tube (spare)	0 8 0	0 5 3
F 1006.—Atomiser Holder	1 13 6	1 2 6
F 1007.—Connection Tube with cock	1 17 0	1 5 0
	£14 3 6	£9 10 9

Gas and Air Supplies. The acetylene gas is best obtained from cylinders of dissolved gas (dissous gas) which may be obtained from various sources, such as, in Great Britain, the British Oxygen Company Ltd. Compressed air may also be obtained in cylinders or may conveniently be supplied by the compressor outfit listed below.

Air Compressor and Accessories.

F 1009.—Air Compressor	£13 18 0
‡**F 1010.—1½ H.P. Electric Motor** for compressor	14 16 6
F 1011.—Cast Iron Base Plate for motor and compressor ...	7 16 0
F 1012.—Starter for motor	6 11 0
F 1013.—Mild Steel Air Receiver	7 13 0
F 1014.—Automatic Air Unloader	2 6 0
F 1015.—Air Intake Filter	0 12 6
	£53 13 0

* This price includes duty upon the special Lundegårdh burner and accessories.
† Prices liable to fluctuate with rates of exchange.
‡ State full particulars of electric supply when ordering.

V.—ADDITIONAL ACCESSORIES OF USE IN A SPECTROGRAPHIC LABORATORY BUT NOT ESSENTIAL.

ALL ACCESSORIES FOR QUANTITATIVE METHODS APPEAR ON PAGES 25-29 AND 50-56.

	For Details see Pages	
*F 1023.—Intermittent Arc Stand (for D.C.) on mount for bar E 481	34	£56 0 0
*F 898.—Potentiometer for obtaining necessary low voltages	34	4 0 0
*F 899.—Resistance for varying motion of lower electrode	34	1 4 0
F 558.—R.U. Powder, in tube containing 2 gms.	38-39	2 10 0
F 559.—Enlargements of the Arc Spectrum of R.U. Powder	39	3 15 0
F 638.—Hitchen Sparking Tube, for solutions ...	36	3 15 0
F 338.—*Atlas de Spectres d'Arc* (Bardet)	48	3 0 0
Apparatus for Measuring and Comparing Spectra.		
L 76.—6-INCH Photomeasuring Micrometer ...	44	98 0 0
F 950.—DEKKOR † Spectrum Viewer	41-42	38 0 0
F 971.—Adjustable Resistance for above F 950	42	1 15 0
or *F 972.—Transformer for A.C. supply for above F 950	42	2 5 0
*L 46.—Judd-Lewis Spectrum Comparator ...	42-43	43 0 0
L 49.—Scale for Judd-Lewis Spectrum Comparator	43	4 10 0
L 48.—Adapters for holding $4\frac{1}{4}$ in. $\times 3\frac{1}{4}$ in. plates on L46	43	5 0 0
Photographic Accessories.		
F 870.—Two Developing Dishes, porcelain, for plates 10 in. $\times$ 4 in.		0 9 0
or F 1021.—Two Developing Dishes, porcelain, for plates 7 in. $\times$ 5 in.		0 5 6
or F 871.—Two Developing Dishes, porcelain, for plates $4\frac{1}{4}$ in. $\times 3\frac{1}{4}$ in.		0 3 6

* State full particulars of electrical supply available when ordering.
† Trade Mark registered in Great Britain and U.S.A.

PART II

Routine Quantitative Methods

(A) MICROPHOTOMETER METHOD.
(B) LUNDEGÅRDH METHOD.

(For other Quantitative Methods see pages 50 to 56).

A. *Quantitative Spectrum Analysis using the Microphotometer.*

For routine methods of Quantitative Spectrum Analysis the microphotometer is found to give the most rapid consistent results. Its use is discussed in a paper by Twyman, Lothian and Dreblow (*J.S.C.I.* March, 1937). Copies can be supplied free on request.

The Non-Recording Microphotometer is used to measure the relative intensities of neighbouring spectrum lines of the major and minor elements and a method of plotting the results, described in the above mentioned paper, eliminate the need for corrections for plate-constants, etc.

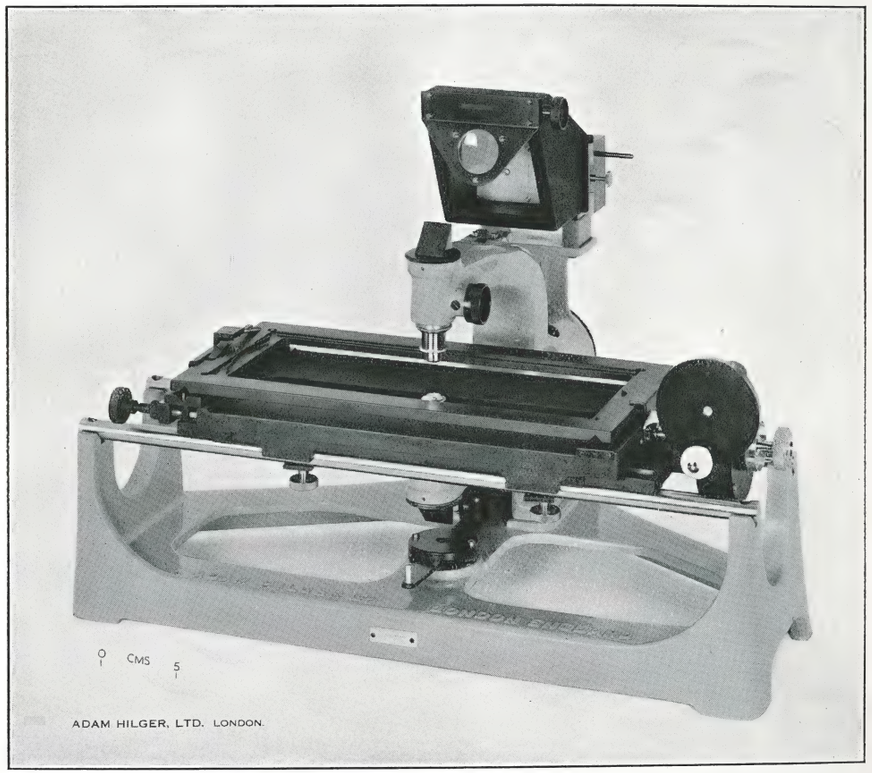


Fig. H 451/405. Non-Recording Microphotometer.

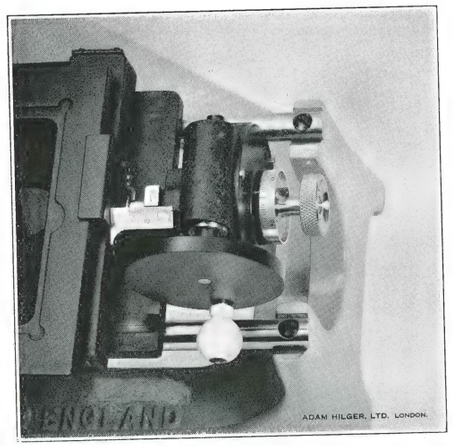
THE HILGER NON-RECORDING PHOTOELECTRIC MICROPHOTOMETER.

(*For a detailed description see Hilger Publication No.* 208).

MICROPHOTOMETER FOR EMISSION WORK.

In spectroscopy it is often necessary to measure the density of lines in spectrograms. The recording microphotometer has for some time been regarded as the standard instrument for such measurements, but it probably happens more often than not that measurements are required to be made at a few wavelengths only on a spectrogram, and in these cases, a much simpler instrument, reading directly on the lines required, is quicker to use, less cumbrous, and far less expensive to make. We have therefore introduced such an instrument, which is described briefly below.

The light from a small electric lamp is projected by an optical system through the spectrum negative under examination on to a photo-electric cell. The same optical system projects an image of the spectrum negative in the plane of a slit situated in front of the cell so that the light reaching the cell is that passing through the spectrum line which is actually imaged on the slit. Hence when the cell, which is of the rectifier (or blocking-layer, or sperrschicht) type, is connected with a suitable galvanometer the deflections of the latter will be proportional to the densities of the spectrum lines.



Fine-Slow Motion of Non-Recording Microphotometer

The knurled head with divided drum turns the micrometer screw directly. The fine-slow motion is actuated through the black disc with white knob, in foreground.

Since the cell is of the rectifier type no batteries are required for the instrument other than those used for supplying current to the 6 volt, 18 watt lamp which is the source of light in the microphotometer.

The stage will accommodate full size (10 × 4 ins.) spectrum plates and, in addition to a coarse movement by hand, is fitted with a short range micrometer screw motion.

For quantitative work the microphotometer has been improved by the addition of an additional fine-slow motion.

The fine-slow motion, a reducing gear added to the micrometer screw which pushes the plate carriage, can be conveniently operated at a speed of one turn per second. About 20 seconds at this rate suffice to traverse a given spectrum line across the slit of the microphotometer and the minimum reading of the galvanometer during this transit can be accurately observed. This removes the necessity for repeating the readings. A considerable saving of time is thereby effected, and a single observer can now make a very large number of routine quantitative analyses in the course of a day's work.

The ordinary fine screw motion can be operated at will so that for selecting the required spectrum lines two degrees of coarse movement are available in addition to the very fine adjustment used for actual measurement.

This instrument is compactly designed, is simple and quick to operate and is well adapted to such comparative measurements as are required for quantitative spectrum analysis.

For economy in time and increase of accuracy in routine analysis many spectra are usually recorded on each plate. As a consequence the individual spectra are narrow. The Hilger Non-Recording Microphotometer has been designed for use on spectra down to 1 mm. or less in length. It also embodies special means of overcoming the effects of grain, which become more noticeable as the spectra are narrower.

The "viewing lens" on the instrument provides a very exact parallax method of focussing the spectrum image, which is desirable when using the ordinary commercial photographic plates.

A modified instrument, specially adapted to the Lundegårdh Flame Method (see page 28), can be supplied. It consists of the new model microphotometer whose stage is fitted with a cross motion, to which is added a ratchet movement H 458 so that lines of the same wavelength in a succession of suitably spaced spectra can rapidly be measured. This basic instrument also requires the H 405 Photocell Unit.

H 451.—Non-Recording Microphotometer (basic instrument) with fine-slow motion	£110	0	0
H 405.—Photocell Unit for use in work on emission spectra ...	12	0	0
H 458.—Ratchet Attachment for automatically bringing successive exposures into position, extra	25	0	0

ACCESSORIES.

A Galvanometer is necessary to complete the apparatus. This should have a resistance of 600-700 ohms approximately; the sensitivity required varies somewhat according to the nature of the work to be done, but a galvanometer which will detect a current of 10^{-9} amps. is sufficiently sensitive for any purpose. We list one which fulfils these conditions when used with a scale distance of 2 metres.

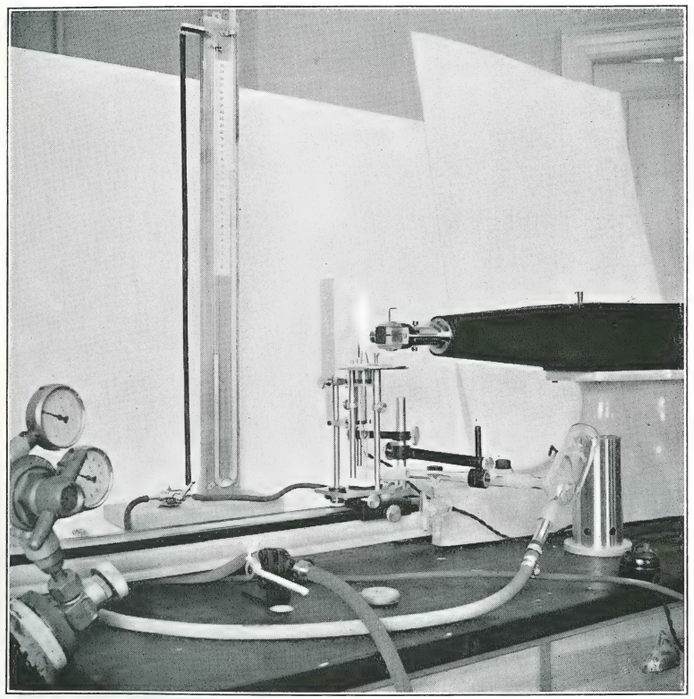
F 878.—Cambridge d'Arsonval Galvanometer, 700 ohms resistance approximately; sensitivity at 2 metres, 1000 mm. per micro-amp. (made by the Cambridge Instrument Co., Ltd., London and Cambridge)	£4	15	0
F 93.—Lamp and Scale for Galvanometer (with 4-volt lamp) ...	4	0	0
F 1045.—Variable Shunt for use with F 878 Galvanometer ...	4	15	0

N.B.—A complete outfit for emission work consists of H 451, (with or without H 458), H 405, F 878, F 93, F 1045.

PROF. H. LUNDEGÅRDH'S FLAME SPECTRUM METHOD OF QUANTITATIVE SPECTROGRAPHIC ANALYSIS

This method, which is described in detail in *Die Quantitative Spektralanalyse der Elemente* (Part II) by H. Lundegårdh*, differs very considerably from the others which have been described. It has principally been employed for such investigations as soil analysis and has given particularly good quantitative analyses of liquids. Use is made of an acetylene-compressed air flame into which is introduced an atomised solution of the substance to be examined. The solution is atomised in a special sprayer chamber by the compressed air supply to the flame. The vapour, mixed with acetylene gas, is burnt in a specially designed burner.

By carefully controlling the gas and air pressures with which the apparatus is fed the flame conditions can be regulated with great consistency and consequently the reproducibility of results is very high. An electrically operated shutter is a considerable aid to the accurate timing of the photographic exposures.



Complete Apparatus as set up in Prof. H. Lundegårdh's Laboratory.

* See also "Annals of the Agricultural College of Sweden" (Uppsala) **3**, 44-97 (1936). (In English.)

The photographic density of a selected spectrum line in a series of exposures is measured by means of a microphotometer. For this purpose we recommend the use of the Hilger Non-Recording Photo-Electric Microphotometer * fitted with a plate shifting gear which automatically moves the plate so as to bring the same line in a succession of spectra in position for measurement.

The Lundegårdh Burner consists essentially of a vertical tube at whose base is a silver jet for the acetylene gas ; air containing the atomised solution enters the burner by a side tube just above this jet. The top of the burner is of platinum (Pt + 10% Iridium). A mount fitting the accessory bar of the spectrograph is provided.†

The Sprayer Vessel, which is connected to the burner, is of special shape and is provided with a ground cone joint fitting the connection to the burner and a larger ground cone joint fitting the glass mount of the atomiser. The latter is made of platinum (Pt + Ir 10%). The sprayer vessel is easily removed from the complete assembly and replaced by a new one, and it is recommended that several such vessels shall be included in the outfit so as to reduce to a minimum any delays caused by cleaning out and refilling them with fresh solution. About 10 c.c. of solution are used.

The Electric Shutter is interposed between the slit and the burner. It is controlled by a simple switch on the bench and owing to its very rapid action it allows of very exact timing of the exposures. The shutter is upon a standard mount for the accessory bar E 481 but can be supplied on a tripod base if desired.

Supplies of acetylene gas and compressed air are fed through the manometers and control cocks from suitable sources. The acetylene is best obtained from cylinders of dissolved acetylene, and the compressed air may be obtained from similar cylinders or from an air compressor.

For a complete list of parts and catalogue numbers, see Outfit IV on pages 22 *to* 23.

Standardisation and calibration of the measurements is carried out by determinations upon standardised solutions. The " Specpure " ratio quantitative solutions mentioned on pages 55 to 56 will be found useful for this purpose.

* See pages 26 to 27.

† If desired a simple tripod base can be substituted.

PART III

Accessories for General Use

CONDENSING LENSES FOR USE WITH QUARTZ SPECTROGRAPHS

For qualitative and semi-quantitative work the use of a condensing lens is sometimes omitted. Where desired, however, the following condensing lenses can be used, they are fitted in Barfit mounts similar to those shown in Fig. F 946 etc.

Type of Spectrograph	Spherical Condenser		Spherocylindrical Condenser.	
	Catalogue No.	Price.	Catalogue No.	Price.
Large (F_D 170 cms.) E 492	F 958	£4 15 0	F 997	£7 5 0
Medium (F_D 60 cms.) E 498 Intermediate (F_D 38 cms.) E 486 Small (F_D 20 cms.) E 484			F 956	£7 5 0

For more refined quantitative work we make the following recommendations :

Until recent years those carrying out spectrum analysis usually wanted to obtain a fairly uniform distribution of illumination along the spectrum lines, and it was customary to use a sphero-cylindrical lens.*

Of recent years it has gradually become recognised that the various problems in spectrum analysis call for three principal different types of illumination :

(*a*) It may be desired that the spectrum should indicate the radiations which are present at all the various positions between the poles of the light source and in this case an image of the light source must be formed upon the slit. This mode of illumination enabled Lockyer to observe the " long " and " short " spectrum lines, and it is used as a means of selecting the middle portion of the iron arc when the latter is used to determine standard wavelengths. It is occasionally of considerable use in spectrum analysis, as for instance in the preliminary selection of " homologous " line pairs.†

(*b*) It may be desired that the spectrum should truly represent the whole of the radiation from the light source, each element of the slit being uniformly illuminated by irradiation from the whole of the light source. The conditions for attaining this are that a real image of the light source should be formed on the prism.

The condensing lens must for this purpose be of " such diameter and focal length, and so disposed, that neither by the margin of the condensing lens nor by anything within the spectrograph are rays obstructed which by passing through each element of the slit to form the real image would thence, on being gathered by the camera lens of the spectrograph, proceed forward to form the spectrum lines on the photographic plate." ‡

* Introduced by Adam Hilger, Ltd., as an improvement on the crossed cylindrical lenses first introduced into spectroscopy by Schumann in 1893 (*Wien. Ber.* **102** IIa, p. 415).

† " The Practice of Spectrum Analysis," 6th Edition, 1935, p. 39.

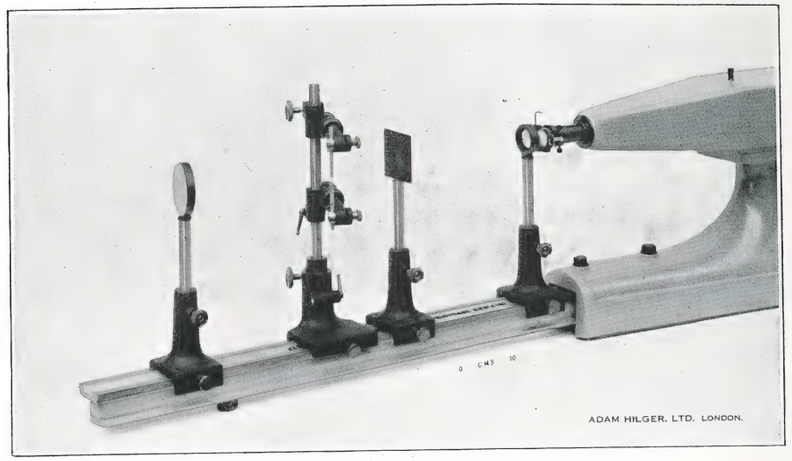
‡ *Proc. Roy. Soc.* **A 133**, p. 74, " The Estimation of Metals in Solution by Means of their Spark Spectra " Twyman & Hitchen.

This mode of illumination and the one following are the most useful in spectrum analysis. They have acquired additional importance in the last few years, because methods of quantitative spectrum analysis have been introduced which are only valid if the spectrum lines are of perfectly uniform intensity throughout their entire length. Examples of such methods are :

(i) The logarithmic sector.*

(ii) The stepped sector † or stepped wedge ‡ used in conjunction with the microphotometer.

(iii) The direct use of the non-recording microphotometer.



(*c*) It may be desired as in the carbon arc cathode layer method to isolate the radiations from any desired portion of the spark or arc, but so to arrange matters that the entire slit is uniformly illuminated by the said selected portion. In this case an image of the light source must be formed upon a screen outside the spectrograph, the portion of interest being allowed to pass to the slit through an aperture of suitable size. An image of this aperture is, at the same time, formed on the prism of the spectrograph by a second condenser. In order that all the conditions required by (*a*), (*b*) and (*c*) may be fulfilled for all wavelengths, it would be desirable theoretically that the condensing lenses should all be achromatic. This, however, entails in practice the use of quartz fluorspar or quartz rocksalt achromatic lenses which are expensive, and the Hilger designers have found that all the conditions can be satisfied with simple lenses of quartz and a single concave aluminised mirror (F1083-1086).

* Twyman, *Trans. Opt. Soc.*, **31**, p. 169 ; 1929-30.

† R. Breckpot, *Ann. Soc. Sci.* Bruxelles **54**, 299 (1934).

‡ D. H. Follett, *Journ. Sci. Inst.* **8**, 221-228 (1936).

The standard condensing systems recommended are as follows :

Type of Spectrograph.	Method of Illumination.	Optical Elements required.	Price on Barfit Mount Fitting Standard Hilger Accessory Bar.	Catalogue No.
All Sizes of Spectrographs E 492, E 498, E 486, E 484, etc.	(*a*) Image of light source formed on the slit	Mirror	£9 0 0	F 1082
Large quartz F_D 60 cms. E 492	(*b*) Lines uniformly illuminated by radiation from the whole of the light source	Lens	£4 15 0	F 1025
Medium quartz F_D 60 cms. E 498		Lens	£4 15 0	F 1026
Intermediate quartz F_D 38 cms. E 486		Lens	£4 15 0	F 1027
Small quartz F_D 20 cms. E 484		Lens	£4 15 0	F 1028
Large quartz F_D 170 cms. E 492	(*c*) Lines uniformly illuminated by radiation from a selected part of the light source	Lens and Mirror	£19 15 0	F 1083 Mirror (F 1082) with lens and diaphragm.
Medium quartz F_D 60 cms. E 498		Lens and Mirror	£19 15 0	F 1084 Mirror (F 1082) with lens and diaphragm.
Intermediate quartz F_D 38 cms. E 486		Lens and Mirror	£19 15 0	F 1085 Mirror (F 1082) with lens and diaphragm.
Small quartz F_D 20 cms. E 484		Lens and Mirror	£19 15 0	F 1086 Mirror (F 1082) with lens and diaphragm.

LIGHT SOURCE OUTFIT FOR ARC.

Gramont Arc and Spark Stand. The latest design of this apparatus (Fig. F 946) is greatly improved and provided with a base which fits the standard accessory bars (E 481-2). The combination of movements permits of a very great variation in height and position of the source.

The horizontal arms are amply insulated, and carry the electrodes in strong screw clamps. To facilitate the rapid interchange of rod electrodes the electrode clamps can be fitted with springs (F 1104). These are only suitable when working with spark discharges.

The whole apparatus is strongly and rigidly built and once set will remain in adjustment. A simple rotary movement of the pillar allows the operator to correct minor deviations in the position of the arc, while it is running. Stainless steel is used for all exposed metal work.

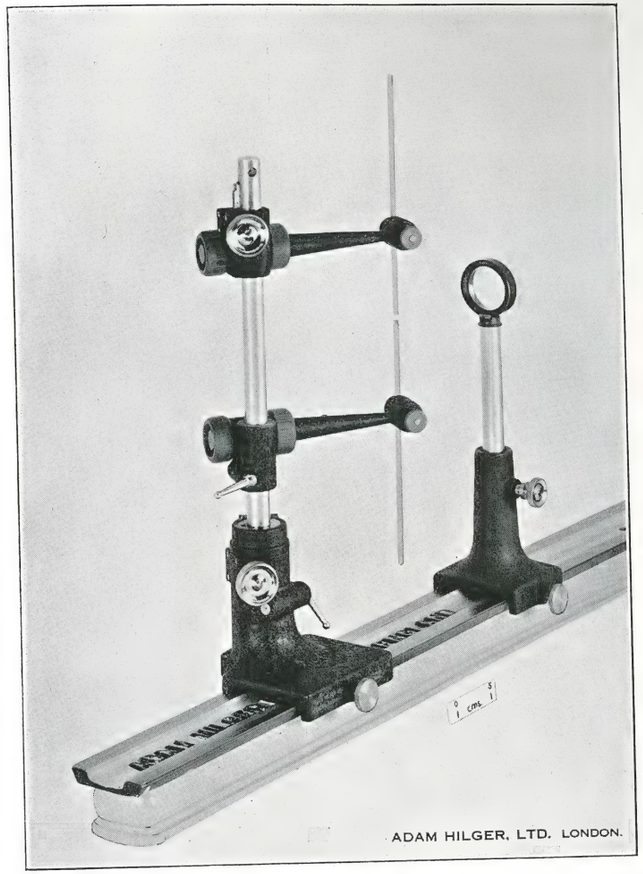
F 946.—Gramont Arc and Spark Stand £16 5 0

F 1104.—Additions for electrode clamps ... ... per set 0 10 0

ELECTRODE HOLDERS.

These are small metal cups on stems, fitted with three screws for gripping small, irregularly-shaped electrodes for the arc or spark. The stems are of a size suitable for being held in the clamps of the Gramont apparatus mentioned above.

F 328.—Electrode Holders ... ... per pair £0 10 6



F 946. The Gramont Arc and Spark Stand on Bar E 481, with Condenser F 958.

CONDENSING LENSES AND LIGHT SOURCE FOR LARGE QUARTZ SPECTROGRAPHS, TYPES E 1, E 383, E 392, E 384, without accessory bar.

Condensing Lenses. The following condensers are mounted directly on the spectrograph so as to be in constant alignment.

E 402.—Spherocylindrical Quartz Condenser in Tubular Mounting for Large Quartz Spectrographs (E 1, E 384, etc.) £10 10 0

E 476.—Spherical Condenser in Cell to interchange with Sphero-cylindrical Condenser of E 402 ... ... 2 0 0

E 371.—Spherical Quartz Condenser in Tubular Mounting for Large Quartz Spectrographs (E 1, E 384, etc.) 8 0 0

E 475.—Spherocylindrical Condenser in Cell to interchange with Spherical Condenser of E 371 ... ... 4 10 0

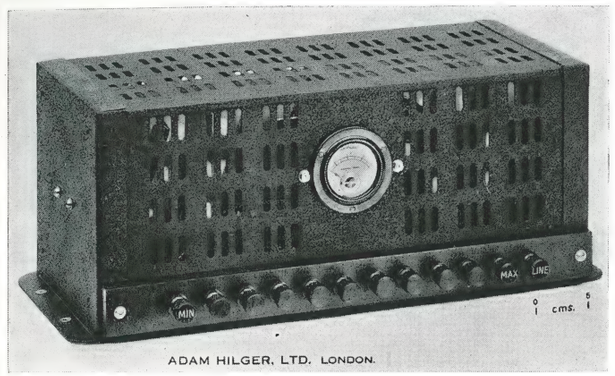
GRAMONT ARC AND SPARK STAND.

This can also be supplied on a tripod base instead of the special base for use on the bar.

F 449.—Gramont Arc and Spark Stand, similar to F 946 but on simple tripod stand £17 5 0

RESISTANCES FOR ARC LAMPS.

This resistance is completely encased in perforated metal, protecting it from damage and the user from shock, while ensuring adequate ventilation and cooling. Twelve terminals provide sufficient tappings for a variation in current values



F 947

between 1 ampere and 8 amperes on 150-250 volts. (For lower currents than 3 amperes the resistance can be used on voltages down to 100.) A small ammeter is mounted on the casing. This resistance is more robust than a lamp resistance and capable of finer steps of variation of current.

F 947.—Metal-clad Variable Resistance for Arc Lamps £5 5 0

THE INTERMITTENT ARC.

It is sometimes desirable that the arc, used as a source of light for spectrographic analysis, should be cool and of short duration, as for instance in the examination of metals of low melting point or in the testing of specimens that would be marred or seriously damaged by an ordinary arc. These conditions can be fulfilled by an arc at a comparatively low voltage made during the separation of two pole pieces normally in contact. The Intermittent Arc performs this last function continuously and automatically. It resembles a Gramont Arc and Spark Stand but one electrode holder is oscillated rapidly by an electric motor.

For solid electrodes a direct current of 80 volts is employed. The current during contact is adjusted by an auxiliary resistance to from 2 to 5 amperes according to the thickness of the electrodes. The best current to take must be ascertained by trial, but the thicker the electrodes the higher is the current required.

***F 1023.—Intermittent Arc** (D.C.) on base to fit accessory bar E 481	£56 0 0
***F 882.—Intermittent Arc** (D.C.) on tripod base	56 0 0
***F 898.—Potentiometer** for obtaining necessary low voltages, for use with F 882	4 0 0
***F 899.—Resistance** for varying rate of motion of lower electrode	1 4 0

* (Please state voltage of supply when ordering this apparatus.)

OUTFIT FOR SPARK.

The spark spectrum is to be preferred for certain work. The outfit described below has been carefully selected as the simplest and most satisfactory means of producing the spark.* It should be used in conjunction with the Gramont Arc and Spark Apparatus mentioned above.

TRANSFORMER SET.

This has been carefully selected as a most useful and convenient outfit for the purpose. It consists of two units, a transformer and a tapped auto-transformer. By connecting the mains and the transformer to the appropriate terminals on the auto-transformer the set can give outputs between 8000 and 15,000 volts when fed with any voltage A.C. from 75 to 220 volts. The set is accompanied by full instructions including tables of connections for various output and input voltages.

The transformer set is used in conjunction with a condenser of about 0·005 m.f. capacity, specially selected for the purpose.

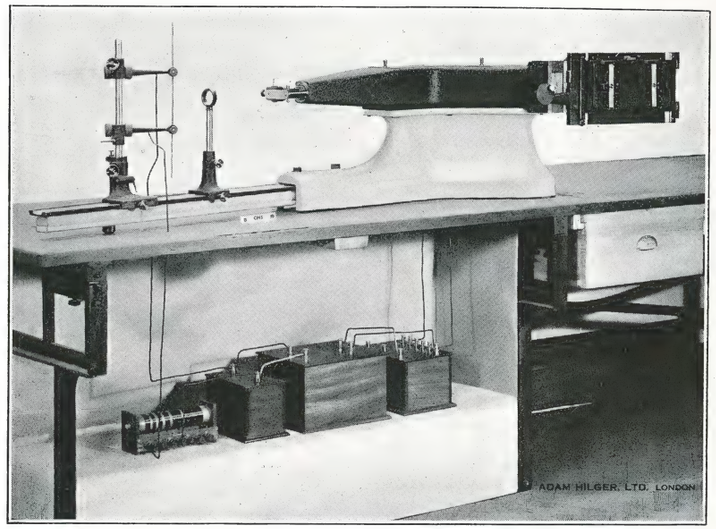


Fig. F 282, etc. Complete Spectrographic Outfit for Spark Spectra. Underneath bench, left to right, F 285 Hemsalech Coil, F 283 Condenser, F 282 Transformer and Auto-transformer.

The above are encased in polished wood and have ebonite tops with nickel-plated terminals.

The Hemsalech air-cored self-induction coil, with which the set of high tension apparatus is completed, has a total inductance of 1·0μH. and is provided with tappings at 0·03, 0·06, 0·13, 0·25, 0·5, 1·0μH., so that ample control over the conditions of excitation of the spark source can be obtained. Its purpose is the elimination of " air lines " from the spark spectrum. Actual trial by competent spectroscopists has been the basis of selection for this outfit.

* See also *Special Note* on page 18.

F 282.—$\frac{1}{4}$ K.W. Transformer and Auto-transformer £20 0 0

F 283.—Condenser of about 0·005 m.f. capacity 11 5 0

F 285.—Hemsalech Self-induction Coil 5 0 0

When there is no Alternating Current supply available it will be necessary to use a Motor-Alternator as described below.

F 281.—$\frac{1}{4}$ K.W. Motor Alternator Set, supplied for D.C. input at either 110 volts or 220 volts, delivering 60 cycles A.C. at 75 volts or 150 volts respectively. Complete with starting and control gear £20 0 0

In ordering F 281 please state voltage of D.C. supply.

SPARKING TUBE FOR SOLUTIONS.

F 638.—Hitchen Sparking Tube for Solutions (designed by C. Stansfield Hitchen, B.Sc., Ph.D.).

This tube has been specially designed to avoid incrustation of the electrodes. Fresh solution is fed to the lower electrode from a reservoir, through a small, annular, fused silica jet. It can be held conveniently in a Gramont Arc and Spark Stand £3 15 0

HIGH FREQUENCY SPARK APPARATUS.

In " Clinical and Pathological Applications of Spectrum Analysis " (see page 48) Wa. and We. Gerlach describe the use of a high frequency spark for spectrographic analysis and in particular for the analysis of pathological preparations. The circuit there described includes a simple transformer set similar to that mentioned above, a Tesla coil, an auxiliary spark gap and a special plate electrode. The following are suitable accessories. We have successfully used our own $\frac{1}{4}$ kw. Transformer Set in this connection, but can, if customers so desire, quote for the more powerful transformer specified by Gerlach.

F 963.—Tesla Coil as specified on page 10 of the above mentioned work £8 0 0

F 993.—Auxiliary Spark Gap, enclosed 7 10 0

F 964.—Plate Electrode with one glass plate. This is a slightly simpler modification of the model described by We. and Wa. Gerlach 0 15 0

F 965.—Spare Glass Plates for Plate Electrode 0 0 6

ELECTRODES, ETC.

HIGH PURITY ELECTRODES.

Particulars of other substances available will be found in our booklet (S.B. 94) *"Hilger Spectroscopically Standardised Substances"* (*post free*). *They include Rare Earths as well as Silver, Gold, and other metals. A wide range of pure solutions of known concentration is available in the "Specpure" Substances* (*see Hilger Publication No.* 168).

A supply of electrodes of high purity, whose analysis is very accurately known, is an essential part of the equipment of a Spectrographic Laboratory. Such electrodes are provided in the Hilger Spectroscopically Standardised (H.S. Brand)* Substances. These are carefully selected after an exhaustive investigation of the sources of supply in the world. They are of an unusual degree of freedom from impurities (in many cases they are specially prepared), and are accompanied by an analytical report, including a list of the lines other than those of the substance itself which appear in spectrum analysis on a quartz spectrograph.

The following are most suitable for general purposes.

F 948.—H.S. Brand Copper Electrodes, 5 mm. dia., 15 cm. long ... ... Per Pair 5s. 0d. Per Doz. Pairs £2 10 0

F 693.—H.S. Brand Electrolytic Iron Electrodes, 5 mm. dia., 17·5 cm. long ... Per Pair 7s. 6d. Per Doz. Pairs 4 0 0

The following Graphite Rods are specially prepared for spectrographic work. They are supplied in two sizes, with full chemical and spectrographic analytical report.

F 623.—H.S. Graphite Rods, 10 mm. diameter 30 cm. long ... ... Per Pair 5s. 0d. Per Doz. Pairs £2 10 0

F 624.—H.S. Graphite Rods, 6½ mm. diameter 30 cm. long ... ... Per Pair 4s. 0d. Per Doz. Pairs 2 2 0

H.S. Carbon Rods of very high purity, containing traces only of B, Ca, Cu, Mg, Fe. These Carbon Rods are purer than the H.S. Graphite Rods and have the advantage that they will arc on alternating current. They are supplied with spectrographic report of impurities.

F 890.—H.S. Carbon Rods Solid, 20 cm. long × 5 mm. diameter. Each 7s. 6d.; Per ½ Doz. £2 0 0.; Per Doz. £3 5 0

Carbons for the Cathode Layer Method of Spectrum Analysis (see Strock "Spectrum Analysis by the Carbon Arc Cathode Layer").

F 1067.—Carbon Electrodes with hole 1 mm. diameter, 2 mm. deep Each 2s. 0d. Per Doz. £1 1 0

F 1068.—Carbon Electrodes with hole 0·8 mm. diameter, 6 mm. deep ... ... Each 2s. 0d. Per Doz. £1 1 0

* H.S. is registered as a Trade Mark in Great Britain and U.S.A.

The following rods may also be found of use.

F 429.—H.S. Nickel Rods of very exceptional purity. A limited quantity of nickel rods of exceptional purity, 5 mm. diameter, 15 cm. long is available Price each £0 3 6

F 403.—H.S. Pure Silver in Rods of 7 mm. diameter × 10 cm. long. These are specially purified for spectroscopic purposes, with the intent that they will prove the purest of all electrodes. They contain at the most an extremely minute trace of copper—very much less than the very small trace in the exceptionally pure iron and carbon electrodes supplied by us. They are cast and not drawn, in order to avoid contamination. Price each, £1 17s. 8d.; Price per pair 3 13 0

In order to avoid contamination by contact with electrical apparatus, etc., it is necessary to wrap the electrode round with a piece of silver foil 0·25 mm. thick, 2·5 cm. square, and to connect with silver wire 1·2 mm. thick by 15 cm. long. These accessories are of the highest commercial purity, but not of the very exceptional purity of the electrodes.

F 404.—Silver Foil as described above ... ... Per piece £0 2 6

F 405.—Silver Wire as described above ... ... Per piece 0 2 0

F 471.—H.S. Bismuth in rods 5 mm. dia., 10 cm. long Per pair, 10s.; Per doz. pairs 5 5 0

F 413.—H.S. Tungsten Rods of very exceptional purity. In rods 4 mm. diameter, 10 cm. long. Limited supply only is available ... ... Price each 2 8 0

F 494.—H.S. Molybdenum in rods 5 mm. × 15 cm., very pure Each 1 3 0

R.U. POWDER.

A new and rapid means of spectrographic analysis consists of the photography beside that of the unknown, of a comparison spectrum yielded by a substance containing fifty elements in such proportions that only a few lines known as their Raies Ultimes are shown. Thence, by reference to photographic charts, the identification of the impurities from which foreign lines in the spectrum of the unknown originate can be made *without determining the wavelengths of the lines.*

The arc spectrum is excited by placing the powder on one of a pair of pure H.S. Graphite or Carbon Electrodes, and striking an arc between them.

Accompanying the R.U. powder is a booklet giving details of the method of its use and a list of the *arc* lines emitted by it, together with indications of their relative intensities and sensitivities. This booklet is of use by itself as a table of the Ultimate Lines for the *arc* spectra of the fifty elements concerned.

The Elements present in the powder are :

Li, Na, K, Rb, Cs, Cu, Ag, Au.
Be, Mg, Ca, Sr, Ba, Zn, Cd, Hg.
B, Sc, Y, La, Al, In, Tl.
C, Si, Ge, Sn, Pb, Ti, Zr.
P, As, Sb, Bi, V, Nb, Ta.
Cr, Mn, Fe, Co, Ni.
Mo, Ru, Rh, Pd, W, Os, Ir, Pt.

A set of seven enlargements has been prepared of the Spectrum of R.U. powder taken on a Hilger Large Quartz Spectrograph E 1, with a comparison spectrum of pure iron as a guide to locating the part of the spectrum in which a given line appears. The origin of all the "Raies Ultimes" and sensitive lines is clearly marked on the lower part of each enlargement.

Adam Hilger, Ltd., are appointed sole distributors for R.U. Powder and its Spectrum Enlargements which are devised and prepared in the Research Laboratories of the General Electric Co., Ltd., at Wembley.

F 558.—R.U. Powder in Tube containing 2 grams (sufficient for 100 to 200 exposures), per tube £2 10 0

F 559.—Enlargements of the Arc Spectrum of the R.U. Powder taken on a Hilger Large Quartz Littrow Spectrograph, E 1. Set of seven, mounted on stiff cards 3 15 0

Printed Tables of the Sensitive **Arc** *Lines of the above* 50 *Elements, including instructions for using R.U. Powder, are supplied free with F* 558 *and F* 559. *These Tables are of value apart from the R.U. Powder and can be supplied separately at* 1*s. per copy post free.*

F 623.—Pure H.S. Graphite Electrodes specially prepared for spectroscopy, and accompanied by a spectrographic report on the impurities found in the spectrum of a representative batch from this source. Recommended for use with the R.U. Powder ... Price per pair £0 5 0

Price per dozen pairs 2 10 0

"SPECPURE" RATIO QUANTITATIVE SUBSTANCES.

These include Ratio Powders in which a specified major element, such as calcium, is mixed with known, minute proportions of a limited number of other elements. Their use is analogous with that of R.U. Powder but permits of quantitative estimations.

See Part V, Other Quantitative Spectrographic Analysis, pages 55-56.

APPARATUS FOR EXAMINING AND MEASURING SPECTROGRAMS.

NEGATIVE VIEWING STANDS.

The examination of spectra is greatly facilitated by the use of this folding stand, in which the negative is placed in a frame in the sloping board while diffuse light is reflected by an opal glass plate in the base. The upper flap protects the stand when folded and aids the observer by screening off much of the surrounding stray light (see fig. F 644).

F 644.—Negative Viewing Stand for plates 10 in. × 4 in.* ... £1 18 6

F. 644. Negative Viewing Stand.

For examining spectrum negatives obtained with Outfit No. III we recommend a smaller and less expensive viewing stand for negatives $4\frac{1}{4}$ in. × $3\frac{1}{4}$ in. only.

F 875.—Negative Viewing Stand for plates $4\frac{1}{4}$ in. × $3\frac{1}{4}$ in. ... £0 7 0

F 217.—Eyepiece with Scale, for examining spectra.

* Can be supplied for 7″ × 5″; $4\frac{1}{4}$″ × $3\frac{1}{4}$″ or 9 × 24 cms. on request.

THE DEKKOR SPECTRUM VIEWER AND ENLARGER.

(The word "Dekkor" is registered as a Trade Mark in Great Britain and U.S.A.

For a full description see Hilger Publication No. 226.

F 950.

This is a specially convenient instrument for the routine examination of spectrum negatives. A portion of the spectrum is projected on a conveniently placed screen and magnified twenty times. The image is projected through the screen, so that it is impossible for any part of the observer to overshadow it. The spectrum negative rests upon a fabric covered platform where it is within easy reach.

Observation with this instrument is very easy and is much less tiring than the use of an ordinary eyepiece or magnifier.

An important feature of this instrument is that the image is erect and therefore moves in a corresponding direction to the plate itself during searches.

The image is so bright that it is possible to use the instrument in a well-lighted room without difficulty. The light source is a 6 volt motor headlamp bulb. For D.C. circuits a variable resistance can be supplied, or for A.C. circuits a suitable transformer is available.

By the addition of a simple photographic attachment the instrument is instantly converted into an efficient fixed focus enlarger.

F 950.—Dekkor Spectrum Viewer and Enlarger (magnification x20) £38 0 0

F 971.—Adjustable Resistance for D.C. or A.C. 110 volt or 200-240 volt circuits 1 15 0
For A.C. circuits a transformer is recommended instead of F 971.

F 972.—Transformer for A.C. circuits 2 5 0

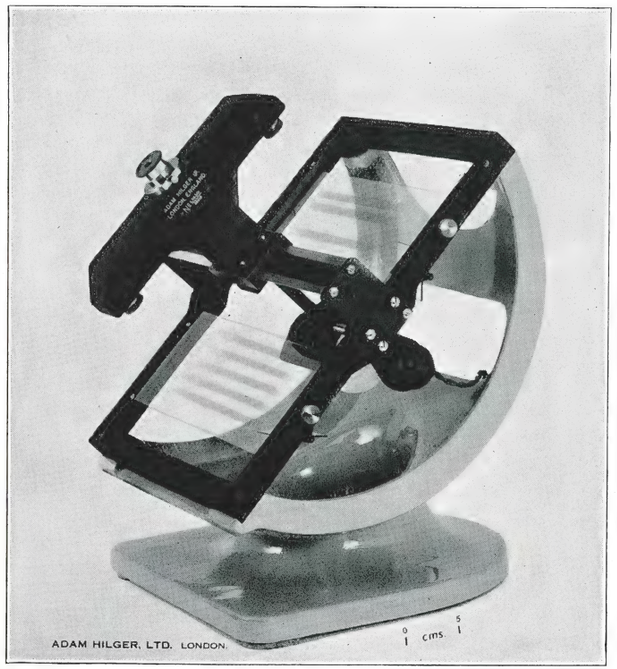
F 955.—Photographic Attachment, including focussing screen and double dark slide for bromide or gas-light paper, or cut film 8½ in. × 6½ in. 11 0 0

F 974.—6 v. 30 w. lamp for replacement 0 4 0

In ordering state particulars of circuit on which apparatus will be used.

JUDD LEWIS SPECTRUM COMPARATOR.

Spectrograms can be viewed in direct comparison with known or standard spectrograms by means of the Judd Lewis Spectrum Comparator. It consists of an open stage with spring holder for the two spectrum negatives, above which, on a long slide, is a double, low power microscope so devised that one half of its field of view is occupied by lines from one spectrum while lines from the other spectrum are visible in the other half. The line of division between the two halves is almost invisible so that the spectrum lines are very easily compared.



L 46.

The instrument has recently been improved by providing it with a rigid metal base (see fig. L 46) inclined at a suitable angle.

Manipulation.—This consists merely in bringing the left hand edge of the plate against the spring bar at the left end of the stage, with slight pressure, as one places the plate on the stage. It is at once, automatically, in approximate adjustment and this is completed by turning either of the milled heads at the right of the stage. The whole operation, including the adjustment, occupies only about five seconds.

Scale.—The instrument can be fitted with a short scale (L 49) hinged to the body of the double microscope in such a way that it can be brought into close proximity with the spectrum negative and used to measure the separations of lines falling within the field of view of the microscope.

Plates may be compared with standards **while still wet,** thus avoiding any delay necessary for drying.

L 46.—Judd Lewis Comparator for plates 10 in. × 4 in. £43 0 0

(Please state voltage of supply when ordering.)

L 49.—Scale for Judd Lewis Comparator 4 10 0

L 48.—Metal Adapters for holding 4¼ in. × 3¼ in. plates per pair 5 0 0

(For full description see Hilger Publication No. 167, post free on request.)

PHOTO-MEASURING MICROMETER.

This is a micrometer especially adapted to the measurement of spectrograms (see Fig. L 76). The platform which will accommodate any size of plate up to 10 × 4 ins. is moved by a fine micrometer screw actuated by a large engraved drum reading to ·001 mms. by a large and readily legible vernier. The micrometer screw controls the whole range of movement of the plate carriage (152 mms.) and is specially accurately cut and so mounted as to realise the full accuracy of measurement.

The microscope is of standard design, with rack and pinion focussing, and is fitted with a 2 in. objective and eyepiece giving a total magnification of 18x. The plate is viewed through the microscope. The micrometer drum is graduated to 0·01.

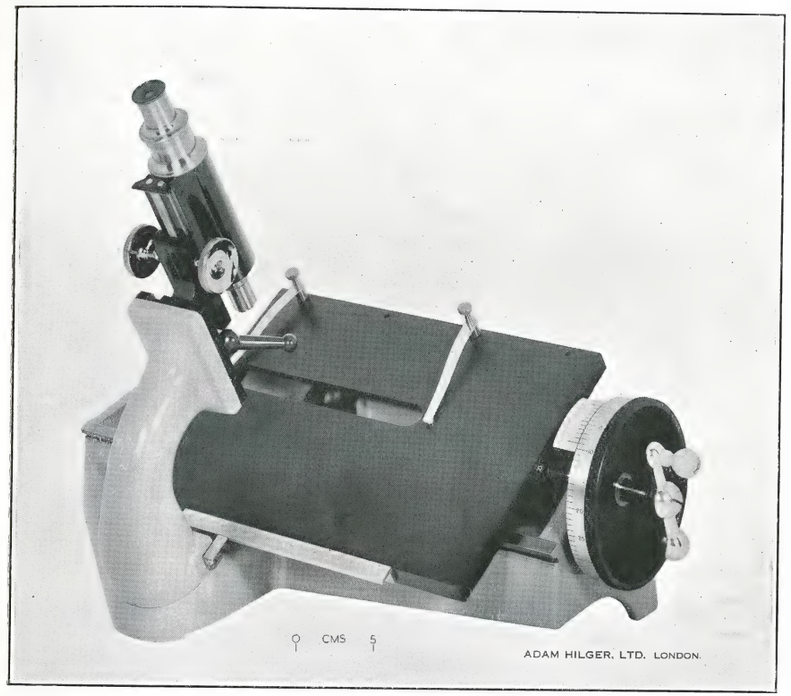


Fig. L 76.—Hilger Photomeasuring Micrometer, six inches travel.

For a more complete description see Hilger Publication No. 260.

L 76.—Photo-measuring Micrometer for Spectrographic Work ... £98 0 0

PHOTOGRAPHIC PLATES.

For General Qualitative and Semi-Quantitative Work.

Ilford Zenith Plates. Speed H. and D. 650. Carefully selected after a full investigation of the relative merits of different types of plate for this work. Sensitive from 2000 A to 5200 A and have moderately fine grain.

F 1016.—Ilford Zenith Plates, size 10 in. × 4 in. ...	per doz.	£0	11	3
F 1017.—Ilford Zenith Plates, size 4¼ in. × 3¼ in. ...	per doz.	0	2	6
F 1018.—Ilford Zenith Plates, size 7 in. × 5 in. ...	per doz.	0	6	8

For Quantitative Work (especially with a microphotometer).

Ilford Ordinary Plates. Speed H. and D. 100. Sensitive from 2000 A to 5200 A have fairly fine grain and considerable latitude. They are especially suitable for quantitative work.

F 1118.—Ilford Ordinary Plates, size 10 in. × 4 in.	per doz.	£0	11	3
F 1119.—Ilford Ordinary Plates, size 4¼ in. × 3¼ in.	per doz.	0	2	6
F 1120.—Ilford Ordinary Plates, size 7 in. × 5 in.	per doz.	0	6	8

For Critical Work requiring the highest possible resolution.

Ilford Thin Film Half Tone. Speed H. and D. 10. Sensitive from 2000 A to 5200 A. Have exceptionally fine grain.

F 921.—Ilford Thin Film Half Tone Plates, size 10 in. × 4 in.	per doz.	£0	11	3
F 922.—Ilford Thin Film Half Tone Plates, size 4¼ in. × 3¼ in.	per doz.	0	2	6
F 1019.—Ilford Thin Film Half Tone Plates, size 7 in. × 5 in.	per doz.	0	6	8

For General Work especially in the Red.

Ilford Rapid Process Panchromatic Plates.

These are recommended, as the result of trial by practising spectroscopists, as the most suitable plate for general spectrographic work in the red end of the spectrum. They are sensitive from the ultra-violet up to 7200 A with normal exposures or to 7900 A with prolonged exposure.

F 142.—Ilford Rapid Process Panchromatic Plates, 10 in. × 4 in.	per doz.	£0	12	3
F 141.—Ilford Rapid Process Panchromatic Plates, 4¼ in. × 3¼ in.	per doz.	0	2	9
F 1020.—Ilford Rapid Process Panchromatic Plates, 7 in. × 5 in.	per doz.	0	7	4

It should be noted that it is not essential to obtain photographic plates for Hilger Spectrographs from us. Customers who are resident outside the British Isles may find it more convenient to purchase plates made in their own countries. Any plates of similar characteristics to the above, provided they are coated on sufficiently thin glass (24-25 to the inch, for the standard 10 in. × 4 in. dark slide), will be found suitable, although the foregoing are selected by actual trial in our laboratories. Plates 4¼ in. × 3¼ in. or 7 in. × 5 in. used for the smaller spectrographs and 10 × 4 in. plates for the E 498 spectrographs are not curved and may be of any thickness.

Such plates are very readily obtainable from Messrs. Ilford, Eastman Kodak, Schleussner, among others.

REFERENCE BOOKS, TABLES, ETC.

The following are recommended :

F 146.—*Wavelength Tables for Spectrum Analysis*, 2nd edition, revised and enlarged (1931). (F. Twyman, F.R.S., F. Inst. P., and D. M. Smith, B.Sc. etc.) ... nett £0 14 6
post free 0 14 11

A book for use in a spectrographic laboratory, and containing only matter essential for this purpose.

It comprises standard wavelengths from 2375 to 8495 I.A. ; and the distinctive spectrum lines of most of the elements arranged both under the name of each element, and also rearranged in order of wavelengths.

For the tables of distinctive spark lines of the elements, the results of Hartley, of Leonard and Pollok, and of A. de Gramont, have been utilised. The object has been not to give complete tables of the wavelengths of the elements, which are available elsewhere, but to give those lines which are present in the photographed spectrum when the quantity of the element is extremely small ; and the authors cited are those who have given this problem most attention.

F 305.—*The Practice of Spectrum Analysis with Hilger Instruments*, 6th edition, 2nd impression (which gives a description of the technique) ... ... nett 0 3 6
post free 0 3 9

A copy of F 305 *is sent gratis with every spectroscope and spectrograph purchased, but spare copies are often of use.*

F 532.—**Enlarged Photograph** of the iron arc spectrum marked with over 1000 wavelengths, including all those recommended as standards by the International Astronomical Union (see fig. F 532 opposite).

A new edition of the above has now been published in eight sections. This incorporates a recent extension into the Red and two enlarged sections between 4325 A and 3305 A.

F 532.—**Set of 8 Enlarged Photographs of the Iron Arc Spectrum** consisting of :

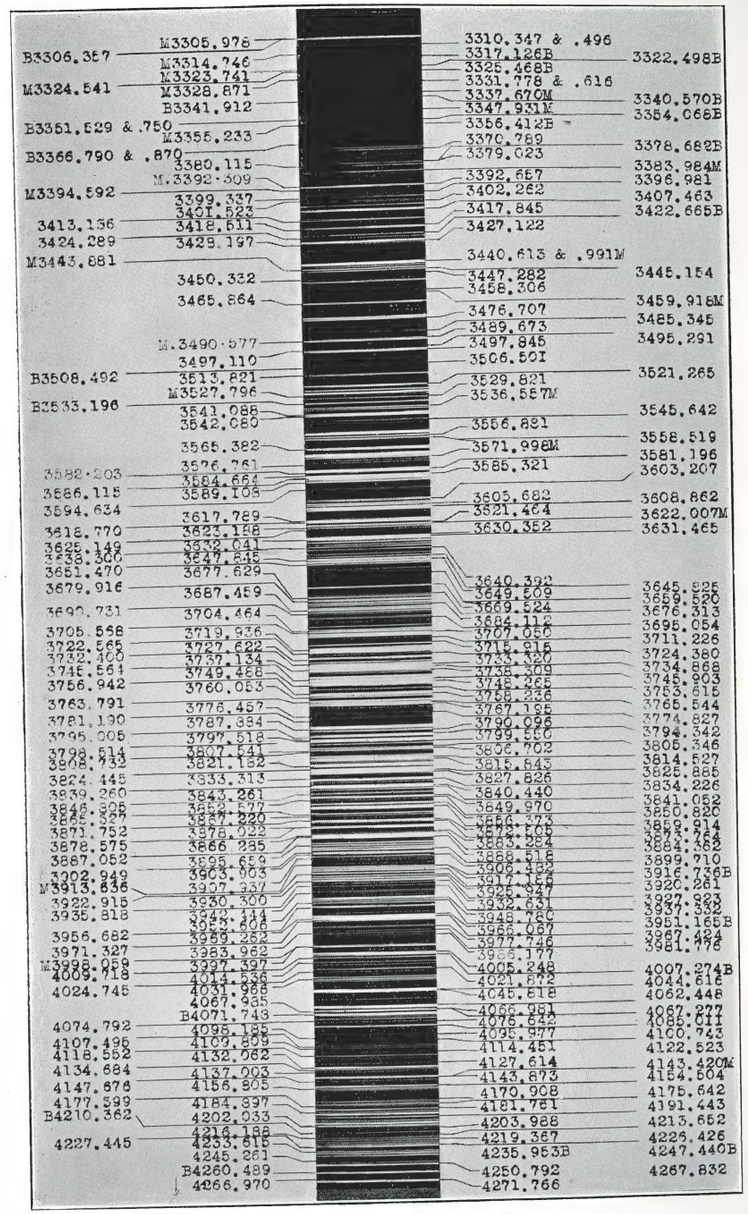
Section	1	from 10216·24	to 6136·618 A.	Section	5	from 3306·357	to 2797·777 A.
,,	2	,, 6677·993	,, 4271·764 A.	,,	6	,, 2797·775	,, 2468·879 A.
,,	3	,, 4325·765	,, 3715·914 A.	,,	7	,, 2245·646	,, 2465·148 A.
,,	4	,, 3711·225	,, 3305·978 A.	,,	8	,, 2245·646	,, 2084·116 A.

Price per set of eight, £2 5s. 0d.

Separate sections can be supplied at 10s. each.

F 152.—**Collotype print** of the Spectrum of Copper marked with Wavelengths, for checking the Wavelength Scale of Quartz Spectrographs. Price, 2s. 0d.

F 304.—**Copper Arc Spectrum.**—Photograph of the copper arc spectrum marked with wavelengths in I.A. in three sections. No. 11.—50 lines from 2043 to 2406 I.A. No. 10.—52 lines from 2406 to 3247 I.A. No. 9—137 lines from 3247 to 5782 I.A. Per set, £1 5s. 0d.
Single sections, 10s. 0d. each.



F 532. Reduced facsimile of a Section of Enlarged Photograph of the Iron Arc Spectrum.

F 338.—Atlas de Spectres d'arc. (J. Bardet.)

This work is particularly addressed to chemical analysts. It gives in 48 figures six series of "tables for analysis," destined for the study of arc spectra. The tables are prepared in the following manner.

The spectrum represented is that of iron as it would be observed by looking at the spectrogram in the microscope. Below this is a graduation in angstroms which permits the wavelengths of the rays to be read approximately in wavelengths. Upon the iron spectrum are found indicated the places occupied by the principal rays of the different elements. With these cards in his hands the observer has only to follow with the eye the spectrum of iron which he sees in the microscope and that on the card, noting the rays which present themselves in the spectrum which he is examining. A glance at the table immediately indicates the origin of these rays.

The author limits the scope of his work to the region 2500 to 3500 A. This, as he says, is the part of the spectrum where one finds the greatest number of sensitive and characteristic rays, and it is also the part in which dispersion of the customary instruments permits precise observations.

The first series of tables permits the investigation of all the usual substances, the five others are intended to facilitate the study of certain analytical groups of elements which give a very much larger number of lines in the spectrum. The text (in French) is clear and precise and the author gives all the details of his technique for obtaining spectrograms and deriving therefrom the maximum of information.

Price *£3 0 0 net, Post free £3 1 0

F 636.—Tabelle der Hauptlinien der Linienspektra Aller Elemente. H. Kayser.

These valuable tables are now out of print and therefore unobtainable. We are informed that a new edition is in course of preparation and may be published towards the close of 1938. *On request we will record the names of customers who would like to have early notice of the publication without any obligation.*

These tables are of very great use in those cases in which the books already mentioned are insufficient. In particular:—

(*a*) When the quantities of substances present are comparatively large. In this case the strongest lines (such as those given in "Wavelength Tables," F 146) are often over-exposed on the photographic plate, and small changes of percentage escape notice. Less prominent lines must then be selected.

(*b*) When, in quantitative analysis, it is necessary to ensure that **no** lines of any other substance that may be present are so close to the selected lines of the substance to be determined as to affect the measurements adversely. The tables are particularly conveniently arranged for this purpose.

F 660.—The Foundations and Methods of Chemical Analysis by the Emission Spectrum. An authorised translation of *Die Chemische Emissionsspektralanalyse*, by Gerlach and Schweitzer. 12s. 6d. net; 12s. 11d. post free.

F 937.—Clinical and Pathological Applications of Spectrum Analysis. An authorised translation, by Joyce H. Twyman, of *Die Chemische Emissionsspektralanalyse*, Part II by Wa. and We. Gerlach.

Although a large part of this latter book is occupied with matter indicated by its title there are also a number of useful tables for qualitative analysis as well as brief accounts of interesting chemical and mineralogical applications.

14s. 6d. net; 15s. 0d. post free.

* Prices are liable to fluctuate with rate of exchange and are subject to confirmation on receipt of an order.

F 996.—Die quantitative Spektralanalyse der Elemente (in German) by Professor Henrik Lundegårdh.

Part 2.—Methodische Verbesserungen und praktische Anleitung für die Ausführung von Analysen in den Gebieten der Biologie, Medizin, Agrikulturchemie und des Bergbaus.

Size Large 8vo. Pages 124 + viii. Illustrated.

Price: In paper covers ... ... *£1 1s. 0d. net., £1 1s. 5d. post free.
Cloth boards ... ... *£1 3s. 6d. net., £1 3s. 11d. post free.

F 1069.—Spectrum Analysis with the Carbon Arc Cathode Layer. By Lester W. Strock, Ph.D., with a preface by Prof. V. M. Goldschmidt. A method developed by Professor V. M. Goldschmidt, Dr. R. Mannkopff, and their co-workers at Göttingen and applicable to non-conducting solids and powders.

Royal 8vo. 56 pages. 20 illustrations and graphs, 5s. 6d. net; 5s. 9d. post free.

F 1064.—"Die Chemische Emissionsspektralanalyse," Part III. Tables for Qualitative Analysis, by Walter Gerlach and Else Riedl.

This book consists almost entirely of tables of the wavelengths of 57 elements and contains lists of those metals whose lines interfere with the lines of the metals being sought.

Royal 8vo. 151 + vii pages, stiff paper covers. *10s. 6d. net; *10s. 9d. post free.

F 867.—Metallurgical Analysis by the Spectrograph, being some experiences of the application of the spectrograph to the analysis of non-ferrous metals and alloys. By D. M. Smith, A.R.C.S., B.Sc., D.I.C. Published 1933. (British Non-Ferrous Metals Research Association).

This book describes some results obtained in recent years in the application of spectrographic methods, particularly to the quantitative analysis of zinc, tin, lead and copper. General principles, technique and its standardisation to ensure reliable quantitative data are explained and illustrated by practical examples.

Royal 8vo., cloth, xii + 114 pp. Ten plates of spectra.
Price 10s. 6d. net; post free 10s. 11d.

F 1034.—La Spectroscopie Appliquée. By P. Swings, with a Preface by M. Charles Fabry.

A clear account of the general methods of qualitative and quantitative spectrum analysis, based on a course of instruction given at the University of Liège.

Paper covers, 8vo., 188 pages. Many illustrations.
Price 4s. 0d.; post free 4s. 3d.*

F 851.—†Spectroscopy in Science and Industry. By S. Judd Lewis, D.Sc. (London), D.Sc. (Tübingen), F.I.C., Ph.C.

An illustrated guide to the principles and technique of qualitative and quantitative spectrographic analysis.

$7\frac{1}{2}$ in. × 5 in., 94 pp. Ten plates of spectra, etc.
Price 3s. 6d. net; post free 3s. 9d.

* Published abroad. Prices liable to fluctuate with rate of exchange, subject to confirmation on receipt of order.

† Prospectus post free on application.

PART IV

Apparatus for Further Methods of Quantitative Spectrographic Analysis

STEPPED SECTOR METHOD.
LOGARITHMIC SECTOR METHOD.
BARRATT'S TWIN SPARK METHOD.
RATIO QUANTITATIVE METHOD.
RAMAGE FLAME METHOD.

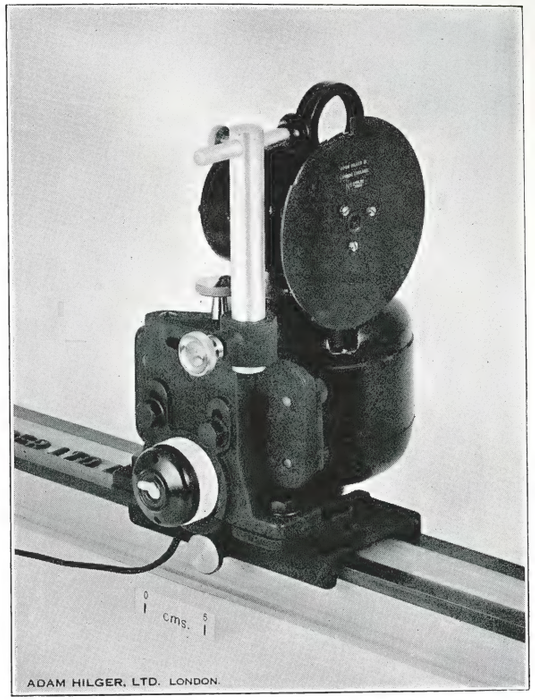
One of the principal aims of workers in spectrographic analysis has been to extend the extraordinarily sensitive qualitative method into a quantitative one. Following on the great developments in spectrum analysis in recent years, several new techniques of considerable promise have come to light almost simultaneously. In each of them there are similar features, though the details are very dissimilar. Each of them depends ultimately on the variation in the intensities of the spectrum lines of an element in relation to the proportion it bears in the main substance. All of them are independent of the chemical separations which are almost always tedious and often extremely difficult. Indeed their rapidity and the ease with which " difficult " alloys or combinations can be attacked are among their chief virtues. A further advantage is that they can be carried out with small quantities.

For a routine method utilising the Non-Recording Microphotometer see pages 25-27.

THE STEPPED SECTOR METHOD OF QUANTITATIVE SPECTROGRAPHIC ANALYSIS.

In this method the determination of the proportions of the substances in an alloy or impure metal depends on the intensities of their spectrum lines, making the comparison with neighbouring lines of the main constituent. The manner in which this is accomplished makes use of a mechanically rotated " sector disc " revolving directly in front of the slit of the spectrograph. The circumference of the disc is cut into a number of steps of equal depth, the angular lengths of which have a definite ratio one to another. The sector rotates in front of the slit in the same manner as the logarithmic wedge sector referred to later but the lines of the resulting spectrogram instead of fading uniformly to an end are divided into sections of decreasing blackness. The ratios of the successive steps being known, the actual intensities of the lines may be deduced as the inverse ratio of the " steps " which are equally blackened. If the lines are suitably chosen this forms the basis of an accurate quantitative analysis of the substance.

To realise the maximum accuracy of this method a microphotometer should be used to measure the blackening ; a suitable instrument is the Hilger Non-Recording Microphotometer described on page 26. Some notes concerning this use of a microphotometer are given byProf. R. Breckpot in *Ann. Soc. Sci.* Bruxelles, **54**, 299 (1934).



H 432. Rotating Stepped Sector on Bar (E 481).

The spectrograph which is to be used for this method of quantitative spectrographic analysis should be provided with a slit so constructed that the planes of the slit and the sector disc may be as nearly coincident as possible. *The slits used on Hilger spectrographs fulfil this condition.*

The conditions of illumination for this method are critical and we specially recommend that the condensers specified on page 53 should be employed. They can be mounted on the sectors as shown in the illustration (but are not included in the price of the sector).

H 432.—Barfit Rotating Stepped Sector, for use with Barfit Large and Medium Spectrographs complete on base with motor	For D.C.	£23	5	0
	For A.C.	24	0	0
H 430.—Barfit Rotating Stepped Sector, for use with Barfit Intermediate and Small Spectrographs complete on base with motor	For D.C.	23	5	0
	For A.C.	24	0	0
H 433.—Rotating Stepped Sector, for use with Large and Medium Spectrographs *without* an accessory bar, complete on tripod base with motor	For D.C.	22	10	0
	For A.C.	23	5	0
H 431.—Rotating Stepped Sector, for use with Intermediate and Small Spectrographs *without* an accessory bar, complete on tripod base with motor ...	For D.C.	22	10	0
	For A.C.	23	5	0

LOGARITHMIC WEDGE SECTOR METHOD OF QUANTITATIVE SPECTROGRAPHIC ANALYSIS.

This method is similar to the foregoing one except that it makes use of a mechanically rotated "wedge sector disc" revolving directly in front of the slit of the spectrograph. This disc is so cut that each portion of the length of the slit has a different length of exposure, increasing logarithmically, from bottom to top. It will be seen that in this case every spectrum line will have a length that is a function of its intensity.

A comparison is made between the lengths (and hence the intensities) of a line in the spectrum due to the metal to be determined and those of its immediate neighbours. Further details of this method * will be found in the *Hilger Bulletin of Spectrum Analysis*, No. 1 (post free).

For the application of this method to spectrography, the following apparatus requires to be added to the ordinary spectrographic equipment, a list of which will be found on pages 17 to 23. The spark, and not the arc, is usually used.

LOGARITHMIC WEDGE SECTOR WITH ELECTRIC MOTOR.

The Rotating Logarithmic Sector is mounted on the spindle of a special electric motor with self-contained reduction gearing on a solid stand which fits the accessory bar E 481. Sectors suitable for the main classes of our spectrographs can be fitted, their contours being suited to the length of slit employed. The reduction gear ensures the sector running steadily at a suitable speed. Motors can be supplied of suitable types for the principal supply voltages. The stand is made of a suitable height for use with our spectrographs. A tumbler switch is fixed to the stand and a length of flex with adapter is supplied.

For spectrographs not furnished with the accessory bar E 481 similar sectors on tripod stands can be supplied; see H 303, H 304 below.

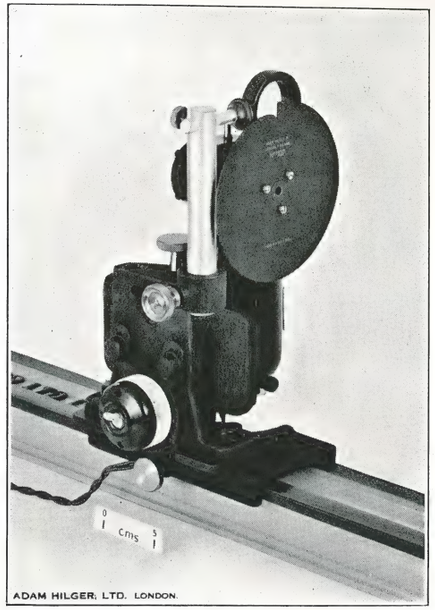
H 425.—Barfit Rotating Logarithmic Wedge Sector, for use with Barfit Large and Medium Spectrographs complete on base with motor ... ... For D.C. £23 5 0
For A.C. 24 0 0

H 444.—Barfit Rotating Logarithmic Wedge Sector, for use with Barfit Intermediate and Small Spectrographs complete on base with motor ... ... For D.C. 23 5 0
For A.C. 24 0 0

H 303.—Rotating Logarithmic Wedge Sector (for Spectrographs, Types E 1, E 383, E 316, etc.) with electric motor, on tripod stand... ... ... For D.C. 22 5 0
For A.C. 23 0 0

H 304.—Rotating Logarithmic Wedge Sector (for Spectrographs E 31, E 37 or E 370) with electric motor, on tripod stand... ... ... For D.C. 22 5 0
For A.C. 23 0 0

* See "Analysis with Wedge Spectra," Morris Slavin, *Engineering and Mining Journal*, Dec. 1933. "The Use of the Logarithmic Wedge Sector for Quantitative Spectrum Analysis," F. Twyman and F. Simeon, *Trans. Opt. Soc.* 31, 1929-30.



H 425. Rotating Logarithmic Wedge Sector on Bar (E 381).

(*In ordering state voltage of supply and in case of A.C. supplies, phase and frequency*).

This apparatus may be used with any spectrograph whose slit is of the requisite length.

For suitable condensing lenses for the above see below.

CONDENSING LENSES FOR USE WITH ROTATING LOGARITHMIC SECTORS AND STEPPED SECTORS.

The following condensers are suitably mounted for direct attachment to the appropriate logarithmic or stepped sectors.

H 438.—Condenser for attachment to Logarithmic Sectors H 425 or H 303 or Stepped Sectors H 432 or H 433 for use with Large Quartz Spectrographs £4 15 0

H 439.—Condenser for attachment to Logarithmic Sectors H 425 or H 303 or Stepped Sectors H 432 or H 433 for use with Medium Quartz Spectrographs 4 15 0

H 440.—Condenser for attachment to Logarithmic Sectors H 444 or H 304 or Stepped Sectors H 430 or H 431 for use with Intermediate Spectrographs 4 15 0

H 441.—Condenser for attachment to Logarithmic Sectors H 444 or H 304 or Stepped Sectors H 430 or H 431 for use with Small Quartz Spectrographs 4 15 0

In order that the Sector shall be correctly used it is essential that a suitable condensing lens shall be used under prescribed conditions. The slit must be uniformly illuminated over the length which may be used. The above lenses fulfil this condition.

The following accessories will be found of use in the observation and interpretation of photographs taken with the foregoing apparatus.

F 644 or **F 875.—Negative Viewing Stand** (see page 40), (included in Outfits Nos. 1, 2 and 3) ... ... £1 18 6 or 0 7 0

H 217.—Eyepiece, with scale for measuring the lengths of the spectrum lines 3 10 0

BARRATT'S METHOD OF QUANTITATIVE SPECTROGRAPHIC ANALYSIS.

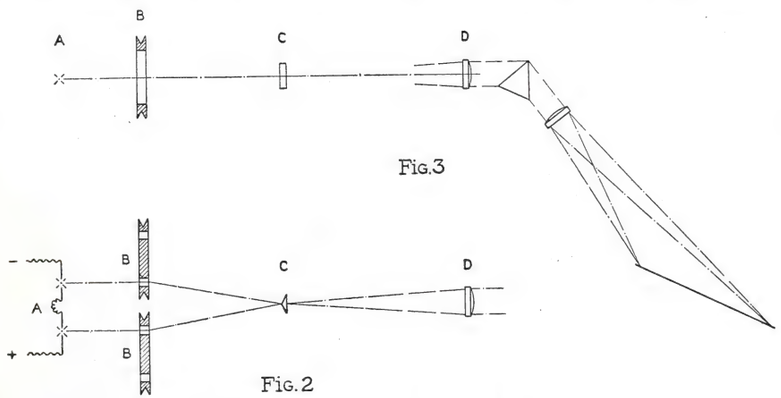
(British Patent No. 320136/28)

(*For a more complete exposition see "Hilger Bulletin of Spectrum Analysis," No. I.*, post free).

The essential features of this method are a twin spark apparatus and the means of photometrically comparing the intensities of lines emitted by each of the two sources, one of which may be of the pure substance.

The Barratt Twin Spark Apparatus consists of a rigid stand carrying two spark gaps which are simultaneously adjustable. Cups with three screws are provided for holding specimens. The two gaps are connected in series and thus similar conditions can be obtained for both sources. A gauge for setting the length and positions of the sparks is fitted.

Hilger Sector Photometer. In addition to the usual Quartz Spectrograph it is necessary to use a Hilger Sector Photometer of a slightly modified form.



H 194a. Paths of Light in Barratt Apparatus.

This consists of an optical system so devised that the light from the two sources, after following separate paths, is brought together on the slit of the Spectrograph and forms two spectra side by side on the photographic plate. Two revolving sector discs, one in the one path being variable in aperture, the other in the other path being constant, provide means of varying the relative exposures of the two sources. Thus, supposing that the radiations of less intensity pass through

the sector of fixed aperture, it will be possible so to reduce the exposure for the other that its spectrum appears to be of exactly similar intensity. Hence, knowing the ratio of the apertures, the ratio of the intensities of the sources may be deduced. In practice a number of pairs of photographs corresponding to a series of known ratios are taken on one plate and the pair of spectra in which the lines of the element sought most nearly match in intensity is selected. From a knowledge of the relative exposure and the " constants " of the substance, the quantity relation can be obtained. The paths of the light from the sources to the photographic plate are shown in the diagram (Fig. H 194A), in which A represents the twin spark, B the sector discs, C the bi-prism on the slit of the spectrograph, of which D is the optical system.

H 447.—BARFIT Barratt Twin Spark Apparatus (as above) ... £19 0 0

Either

H 452.—BARFIT Hilger Sector Photometer modified for use with Barratt Twin Spark; for use with Medium Spectrographs (E 488, E 498) to fit accessory bar E 481 ... 55 0 0

or

H 453.—BARFIT Hilger Sector Photometer modified for use with Barratt Twin Spark; for use with Large Spectrographs (E 492, etc.) to fit accessory bar E 481 ... 55 0 0

Please state voltage of supply in ordering.

(*For details of suitable Spectrographs see pages* 7-13.)

A complete outfit for the Barratt Method consists of the usual spectrographic outfit detailed on pages 17 to 23 (omitting the condensing lens and the spark apparatus F 946), with spark equipment, Twin Spark Apparatus (H 447), and Hilger Sector Photometer (either H 452 or H 453).

" SPECPURE " RATIO QUANTITATIVE SUBSTANCES.

(For full details see Hilger Publication No. 168).

(*Reference* S. JUDD LEWIS, *Chemistry and Industry*, **51**, 271-274, 1932.)*

These substances are highly purified and have been prepared and standardised under the most careful conditions for use in the method of quantitative spectrographic analysis advocated and described by Dr. S. Judd Lewis in the paper cited above.

The basis of this method is the spectrographic determination of the ratio of a minor constituent of the specimen to one or other of its major constituents. The percentage of the major constituent can be accurately determined by chemical means and from this the percentages of the most minute proportions of the minor constituents can be determined even when the quantity of the specimen is itself very small.

The method, in brief, consists of the comparison of the spectrum of the specimen with that of a suitable Ratio Powder or series of Ratio Powders, subsequently synthesising the substance by means of the Ratio Solutions (on the data furnished by comparison with the Powders) and effecting a spectrographic comparison between the

* A limited number of copies of this paper can be supplied by Adam Hilger, Ltd.; post free on application.

original specimen and its supposed counterpart. According to the system, the specimens are so prepared that the comparisons are conducted throughout with chemically similar substances and any modifying effects of component chemicals upon any others are produced in both, the substance and the standard being as nearly as possible alike. Their spectra are therefore strictly comparable so long as the conditions of excitation are maintained constant.

It should be observed that the " Specpure " salts, solutions and powders listed in the above booklet are of practically spectroscopic purity and are accurately standardised. Thus they are equally applicable to the quantitative spectroscopic methods advocated by Hartley, de Gramont, Pollok and Leonard, Hitchen, Lundegårdh, Gerlach and Schweitzer, Ramage, Porlezza and others.

The " Specpure " products are offered in four forms :

1. **Ratio Powders. (Cat. Nos. F 701, F 702.)**
2. **Solid Salts,** usually chlorides **(Cat. No. F 703).**
3. **Solutions 10 per cent. (Cat. No. F 704)** standardised to contain 10 grams of **ANHYDROUS chloride** (or other salt) in 100 c.c.
4. **Ratio Solutions (Cat. No. F 705)** standardised to contain precisely **one gram** of the **ELEMENT** in 100 c.c. for example, Calcium (Ca), in the form of chloride, ready for use in **ANY METHOD** of quantitative spectroscopy. Although this concentration has been selected especially for use in the **Ratio Quantitative System,** it will be found the most convenient when working by the methods of Hartley, Lundegårdh, etc.

The complete list of substances available will be found in Hilger Publication No. 168.

Each supply is accompanied by a full **Chemical and Spectrographic Report** on its purity.

H. RAMAGE'S METHOD.

In the method introduced by Ramage the material to be tested (either as a powder or solution) is placed in a piece of ashless filter paper (Munktell's 00), folded into a tight roll and burnt in an oxy-coal gas flame. The burner consists of two concentric fused silica tubes ; the outer one for coal gas and the inner tube for oxygen.

See H. Ramage, *Nature*, **123**, 601 (April 20, 1929).

F 900.—Ramage Burner	£2 0 0
F 1089.—Barfit Clamp on Stand for Ramage Burner	2 10 0
F 956.—Sphero-cylindrical quartz Condenser	7 5 0

PART V

Users of Hilger Spectrographs

The following are the names of a few of the more important purchasers of our Quartz Spectrographs for metallurgical mineralogical, general chemical and similar investigations. In addition there is a very large number of academic users of these instruments.

THE LARGE QUARTZ SPECTROGRAPH (over 200 of these instruments have been sold).

(E 492, E 1, E 383, etc.). Of these the Fully Automatic Instruments are distinguished by an asterisk *

*Admiralty Inspection Department, Sheffield (2 Instruments).
National Physical Laboratory—Metallurgical Department.
*War Department, Woolwich.
*Research Department, Woolwich.
*The Government Laboratory, London.
General Post Office—Research Station, London.
General Electrical Co., Ltd.—Research Laboratory, Wembley, England.
*Westinghouse Brake and Saxby Signal Co., London.
Siemens Bros. & Co., Ltd., Woolwich.
*British Non-Ferrous Metals Research Association, London.
British Thomson-Houston Co., Ltd., Rugby.
British Insulated Cables, Ltd., Prescot.
Sheffield Smelting Company, Sheffield.
*Vickers-Armstrong, Ltd., Newcastle-upon-Tyne.
Liverpool Nitrate Company.
Rowett Research Institute, Buckburn, Aberdeen.
L. A. Johnson, Esq., Nakura, Kenya Colony.
S.A. Lignes Télégraphiques et Téléphoniques, Conflans St. Honorine, France.
*Institut d'Hydrologie, La Sorbonne, Paris.
*Comité d'Etudes des Métaux à Haute Température, Mons, Belgium.
Union Chimique Belge, Brussels.
*Fabrique Nationale d'Armes de Guerre, S.A., Herstal-lez-Liége, Belgium.
Compagnie des Métaux d'Overpelt, Lommel et de Corphalie, Overpelt-lez-Neerpelt, Belgium.
Physikalisch-Technischen Reichsanstalt, Charlottenburg.
I. G. Farbenindustrie Akt. (Anorg. Lab.), Leverkusen—I. G. Werk.
Laboratoria Geochemie Gadochnych Porod, Moscow.
Central Geological Institute, Moscow.
N.I.G.R.I., Moscow.
Central Institute of Metals, Leningrad.
Moscow Arsenal, U.S.S.R.
Technopromimport, Moscow (2 instruments).
*Technopromimport, Moscow (6 instruments).
*The Limited Company, formerly the Skoda Works Plzn-Skodaworks, Czechoslovakia.

Polytechnos Limited, Montreal, Canada.
Geological Survey—Department of Mines, Ottawa, Ontario, Canada.
*Department of Mines, Province of Quebec.
Food and Drug Laboratory, Dept. of National Health, Ottawa, Ontario, Canada.
*The Hudson Bay Mining and Smelting Company, Flin-Flon, Manitoba, Canada.
*Department of Agriculture, Bureau of Chemistry and Soils, Washington, U.S.A.
A. O. Smith Corporation, Milwaukee, U.S.A.
*American Cyanamid Co., Stamford, Conn.
American Brass Company, Waterbury, Conn.
Anaconda Copper Mining Company, Black Eagle, Montana, U.S.A.
Central Alloy Steel Corporation, Massillon, Ohio.
Calumet Baking Powder, Chicago.
Chase Cos. Inc., Waterville, Conn.
Franklin Institute—Bartol Research Foundation, Swarthmore, Pa.
Follansbee Brothers Co., Brooke County, West Va.
General Electric Company—National Quality Lamp Division, Cleveland, Ohio.
General Electric Company, Schenectady, N.Y.
General Motors Research Corporation, Detroit, Michigan.
Leeds & Northrup Co., Philadelphia, Pa.
Mellon Institute of Industrial Research, Pittsburgh, Pa.
National Smelting Company, Cleveland, Ohio.
R. C. A. Victor Corporation, Camden, N.J.
*Eastman Kodak Co., Rochester, N.Y., U.S.A.
Republic Iron and Steel Co., Youngstown, Ohio.
Union Carbide & Carbon Research Laboratories, Long Island City, N.Y.
U.S. War Dept., Wright Field, Dayton, Ohio.
United Verde Copper Co., Clarkdale, Arizona.
United States Naval Research Laboratory, Anacostia, D.C.
U.S. Naval Research Laboratory, Washington, D.C.
Western Electric Company, Inc., Engineering Department, New York.
Vanadium-Alloys Steel Company, Latrobe, Pa., U.S.A.
Government War Department, Mexico.
*Department of Scientific Research, Dominion Laboratory, New Zealand.
*The Waite Agricultural Research Institute, Glen Osmond, South Australia.
*Munitions Supply Laboratory, Maribyrnong, Australia.
Rhodesia Broken Hill Development Co., Ltd., Northern Rhodesia.
*Minerals Research Laboratory, University of Witwatersrand.
Rubber Research Institute, Kuala Lampur (*through Messrs. A. Gallenkamp and Co., Ltd.*).
Imperial Japanese Navy (2 instruments).
Imperial Steel Works, Japan.
Mitsubishi Dockyard, Nagoya, Japan.
Asahi Glass Co., The Laboratory, Yokohama.
Japan Optical Company, Tokyo.
South Manchuria Railway Company.

THE MEDIUM QUARTZ SPECTROGRAPH (over 680 of these instruments have been sold).

(E 2, E 3, E 315, E 316, E 487, E 488, E 498, etc.)

National Physical Laboratory (2 instruments).
Bureau of Standards, Washington, U.S.A.
Physikalisch-Technischen Reichsanstalt, Charlottenburg.
Royal Mint, London.
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Italian Air Ministry, Research Department, Rome.
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Bureau of Science, Manila, Philippine Islands.
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Victorian Railways Department, Melbourne, Australia.
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Department of Communications—Electro-Chemical Laboratory, Tokyo.

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